Metals and Alloys

THE MAGAZINE OF METALLURGICAL ENGINEERING

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MAY 1941

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Feature Section

What is an Engineer?

This question is interestingly and cogently answered in our leading editorial.

There is a Difference

Those who do not realize the difference between a metallurgical engineer and a metallurgist should read our second editorial.

Airplane Engine Mounts

The various steps in welding the parts of engine mounts for Martin bombers is recounted by Mr. Chase in the leading article.

Heat Treating Steel Castings

The evolution of the heat treatment of steel castings from the practice of early days to the present time is discussed by Mr. Hall, a man of long experience in this field.

Aircraft Engine Cylinder Heads

The various steps in the manufacture of aluminum alloy cylinder heads for airplanes by the Wright Aeronautical Corp. in a new foundry are pictorially presented in our third feature article.

Electrical Contacts

The manufacture of tungsten-copper electrical contacts of various compositions by powder metallurgy methods is described in our fourth article. Properties of the various compositions used are discussed.

Hydrogen in Steel and Cast Iron

The second instalment in a series on the presence of hydrogen in steel or cast iron and its relation to defects in applied coatings is continued.

Petroleum Coke for Harder Iron

The use in the cupola of petroleum coke, which has a higher carbon content than ordinary foundry coke, is reported by Knehans & Berndt (page 608) to produce a higher hardness in cast iron.

Engineering Digests

Gas vs. Infra-Red Lamps

The not-entirely-polite controversy between the proponents of infra-red ray lamps and the advocates of gas heating for the curing of industrial finishes still waxes, with the gas man's side of the picture given on page 618. Did you know there are *gas burners* available, too, for supplying infra-red radiation?

German High Speeds Steels

An interesting table in an article by Voegelin (page 624) on German high speed steels reveals that molybdenum is now more "strategic" to the Nazis than tungsten. The former trend toward molybdenum high speed steels had to be reversed when American molybdenum was denied the Germans, and high-tungsten steels are now more common.

Decarburization Aids Brazing!

This is in a class with 'Man Bites Dog," for, except for its contribution to the production of European (white-heart) malleable, decarburization is generally considered to be a complete evil. According to Kelley (page 628) though, decarburized steel surfaces braze better than non-decarburized. We grow dizzy thinking of the commercial possibilities in selling controlled atmospheres for positive decarburization.

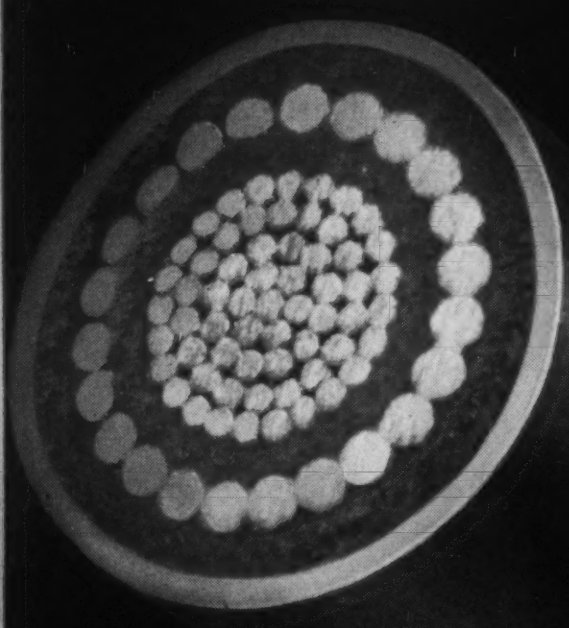
Annealing Aluminum Alloys

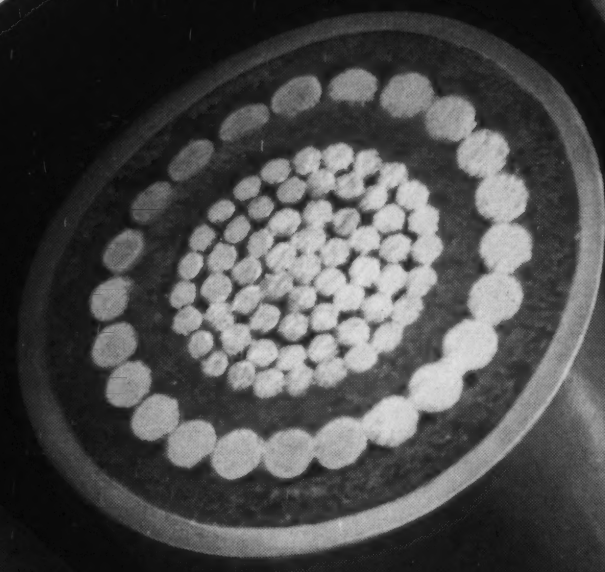
Certain aluminum-magnesium-manganese alloys recrystallize at a lower temperature than pure aluminum, report Bungardt & Osswald (page 632).

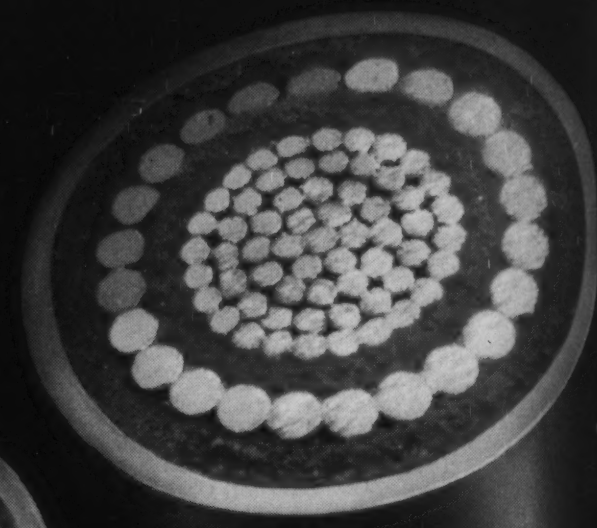
Zinc Alloy Bearings

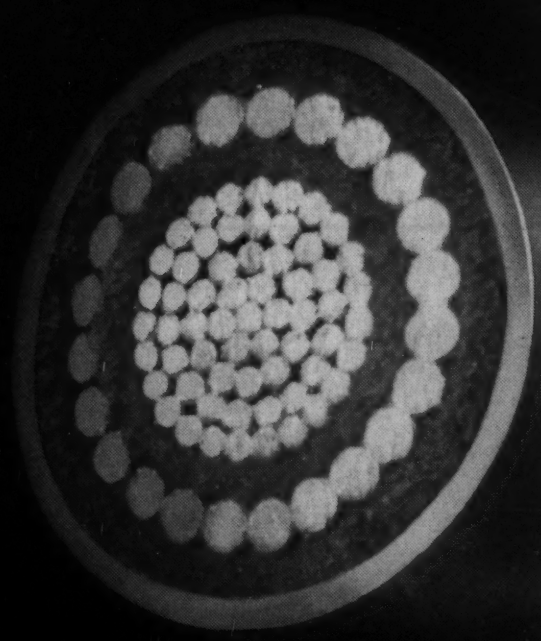
Zinc-base alloys show promise as bearing metals, reports Weber in a composite on page 638. American engineers and the zinc producers can hardly exploit the idea right now, but the producers should investigate this application thoroughly in the face of that inevitable day when the buyer's market returns with a bang! and everyone is scrambling for new products and new markets.

WHY Concentric Cable for Resistance Welding?

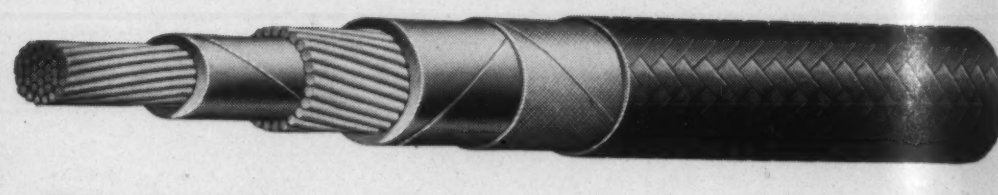








Because It's the Best for the Job



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What's an Engineer ?

We have all heard the definition of an engineer as the man who can do for ten cents what any damn fool can do for ten dollars. A more formal definition was given by Ormondroyd in the March issue of the *Journal of Applied Mechanics:* "An Engineer is one who uses natural materials and energies to maintain human existence with the least possible expenditure of human effort." In other words, he's an aid to laziness, or to having time to go fishing.

This definition makes no distinction among different brands of engineers. Before the other engineering sub-divisions grew up, the term "civil engineer" included all engineers other than "military." In thinking over this definition, one is at first inclined to except the military engineer from those "striving to maintain human existence with the least expenditure of human effort." But he could reply that by going to great temporary expense in human effort and by ending the human existence of as many as possible of the enemy forces, he is, in the long run, hoping to maintain the more effortless existence of the people of his own country.

Certainly a little more expenditure of the proper type of effort at the right time would have avoided the present plight and slavery of France. One might set down, as a corollary to the definition, that an engineer does not hesitate to expend materials, energies and human effort at one time in order to save human effort at a later time.

The labor union racketeer claims that his extortion of initiation fees and dues in order to exercise the right to work has as its ultimate aim the maintenance of the laborer's existence with the least possible work. The politician always claims that his policies are aimed toward providing a practically worklessexistence for all, and it sometimes comes out that way for some of his appointees.

These claims mislead people into actions that often bring just the opposite effect from that promised. The racketeers and the politicians do not employ "natural materials and agencies"; the engineer does. The "natural materials and agencies" follow immutable natural laws so that once the engineer understands those laws, his results are predictable and certain. These laws don't have to be periodically repurchased by union dues nor voted into office.

It's the engineer, and the metallurgical engineer along with others, not the blatherskites, who will see to it that we and our children can both exist and have time to go fishing.—H. W. G.

Mind your own Business ?

In conversation at the lunch table a while ago with an able and well-known metallurgical engineer, we were shocked by a tale he told of cracked castings in which the metal was O.K. but the design rotten. When these facts, which were of course immediately evident to him, were proven, a slight design change cured the trouble.

We asked, "Why wasn't the design submitted to you for comment before the castings were made?" He said, "Oh! in our plant that's the business of the foundry superintendent, not mine." We told him that his organization evidently had a cockeyed conception of the field of the metallurgical engineer. The American Foundrymen's Association has no idea that any water-tight compartment separates the metallurgical engineer and the rest of the plant, for its handbooks pay equal attention to casting design and the composition and properties of the metal that go into those castings.

We recall that once in our own early experience we were discussing purely metallurgical matters with the general manager of the plant we were then working for, and after those things had been thrashed out, he said, "Well, got anything else on your mind?" We said, "Yes, though you may say it's none of the metallurgical department's damned business, why does the plant carry out this operation in this fashion?" He replied, "We'll look into that operation, but you've brought up something even more important. The only people that this plant can hope to develop into positions of greater responsibility are those who do stick their noses into matters that are outside their routine duties. No man ever needs to apologize to me for being curious about anything that affects our operations, and I'll always have time to discuss matters with any of our men. Most of the useful innovations around here came because somebody did stick his nose into what could be termed the other man's business."

(Continued on page 590)

THREE WAYS TO WORK ON THIS PROBLEM OF *STEEL*

FIRST... Place your steel requirements clearly and fairly before your regular source. Explain exactly what you need and *when* you need it. Don't try to get a corner on steel.

SECOND... Determine the physical property requirements for each job. List possible substitutions that may be used if necessary.

THIRD... Fill your immediate requirements with steel from warehouse reserve stocks. To save time send open orders, as needed sizes may be sold while the quotation is being made. You know this method is entirely safe through the Ryerson one-price policy of many years standing. Naturally, some sizes are missing but we can provide prompt shipment on most all steel products from our nearest plant.

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Welding Engine Mounts for Martin Bombers

by HERBERT CHASE

This article describes the various steps which The Glenn L. Martin Co. of Baltimore, producer of many types of aircraft, uses in making engine mounts for Martin Bombers. These mounts are constructed of S.A.E. X 4130 chromium-molybdenum seamless steel tubing and the oxy-acetylene flame is used. The apparatus which is used in the various preliminary and final welding operations is described as well as that necessary to straighten and align the finished product.

The article has a distinct defense and preparedness flavor, supplementing those we published in the October, November and December issues.

—The Editors.

AMONG THE HIGHLY STRESSED STRUCTURES which form parts of the light bombers produced by The Glenn L. Martin Co., Baltimore, Md., are those known as "167" engine mounts. These structures form the supports for the radial cylinder engine, at their front end, and are joined to the nacelle bulkhead at their rear end. They are constructed largely from S.A.E. X 4130 chromium-molybdenum seamless steel tubing having wall thickness ranging from 0.049 to 0.083 in. Sockets at the bulkhead end are steel forgings and the lugs to which the engine is bolted are also forgings, drilled axially, to form a bolt hole, and provided at each end with an ear stamped from sheet stock and welded to the forging. The only remaining parts required to complete the mount are gusset plates which are stamped and subsequently formed to provide U-shaped sections and a contour such as to fit between the tubes they brace in the assembled structure.

All these elements are received by the welding department cut or formed to the required length or shape. The ends of the straight tubes are all milled to such contours as to fit the members to which they are to be joined by welding. One of the major members of the mount is the ring of tube used at the engine end. This is received ready formed to annular shape but without the ends joined by welding.

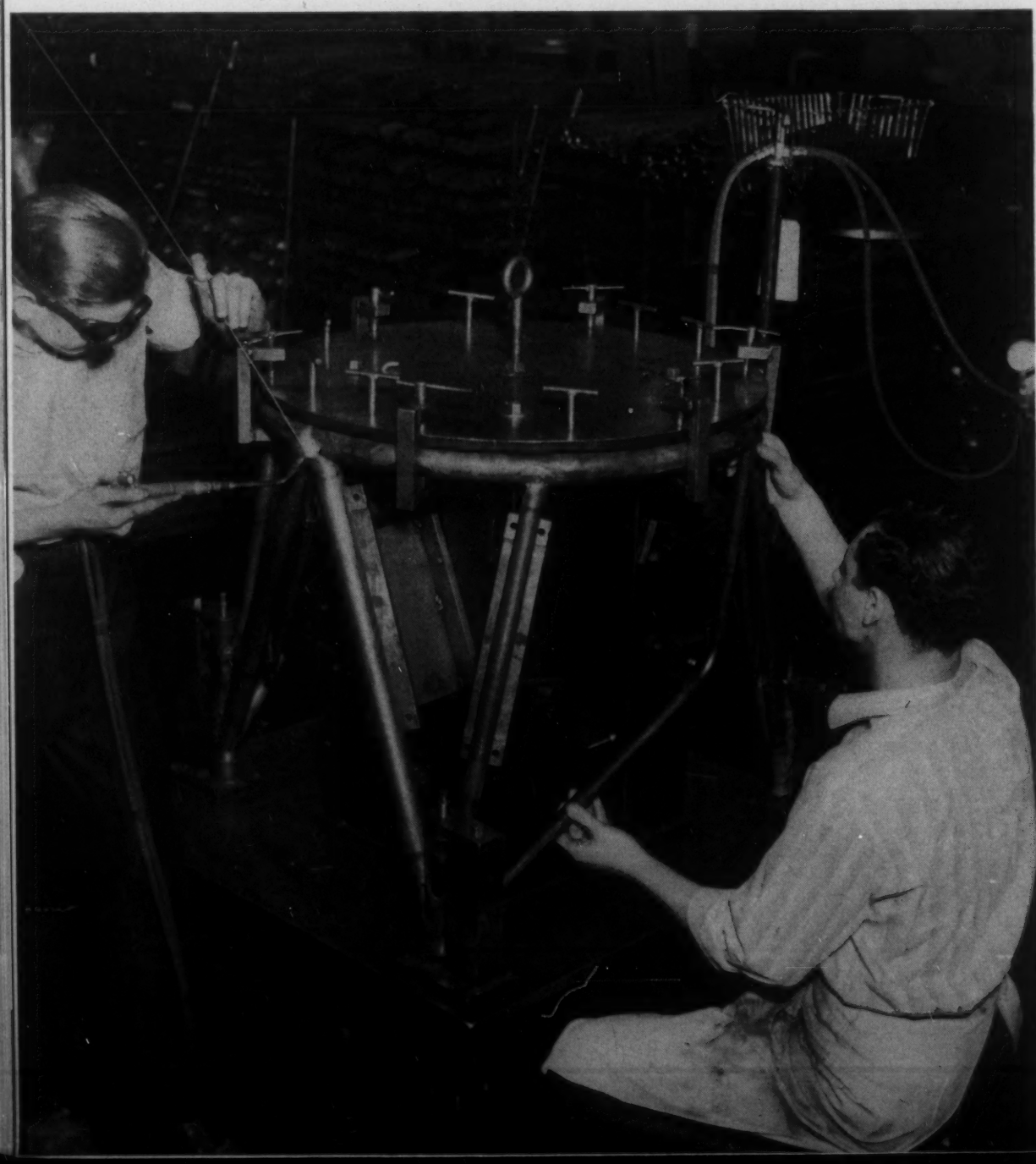
Oxy-acetylene Welding Used

All welding is done with oxy-acetylene torches and, where welding is facilitated by preheating, a flame is used for this purpose. This is required, of course, primarily where lugs and sockets of thick section must be welded to thinner metal. Welding rod is of 1/16-in. diameter and of low carbon steel which is found to pick up, in the welding process, enough of the alloying elements from the parts welded to insure joints of ample strength.

The first major welding operation joins the ends of the tube which forms the ring, but, while this is proceeding, the lugs to fit the ring are built up by welding ears to the short lengths of bar, which are really thick-wall tubes, since they already have an axial hole. These minor sub-assemblies are welded at benches, and the next operation, on the main assembly, is to tack weld the ears of the lugs to the annular tube. This is done in a flat jig with pins which hold the lugs in correct position while they are being tack welded. Next, the ears of the lugs are welded to the annular tube over the full length of arcs where the ears contact with the tube.

A Stretching Jig

This completes the first major unit of the main



A jig in which the major elements of the engine mount are correctly positioned and tack welded as a preliminary to the final welding operations which follow after the tack welded assembly is removed and mounted as a welding stand.

Another view of the operation of correctly positioning and tack welding the major elements of the engine mounts.

A portion of the department in which the engine mount described in the text is acetylene welded. In the foreground are shown some of the welding stands arranged for convenient rotation of the work so that all welds can be made in a position below the flame. To the right are seen the fixture used in tack welding lugs to the ring and one for stretching the ring thereafter to bring the lug holes into correct radial position.

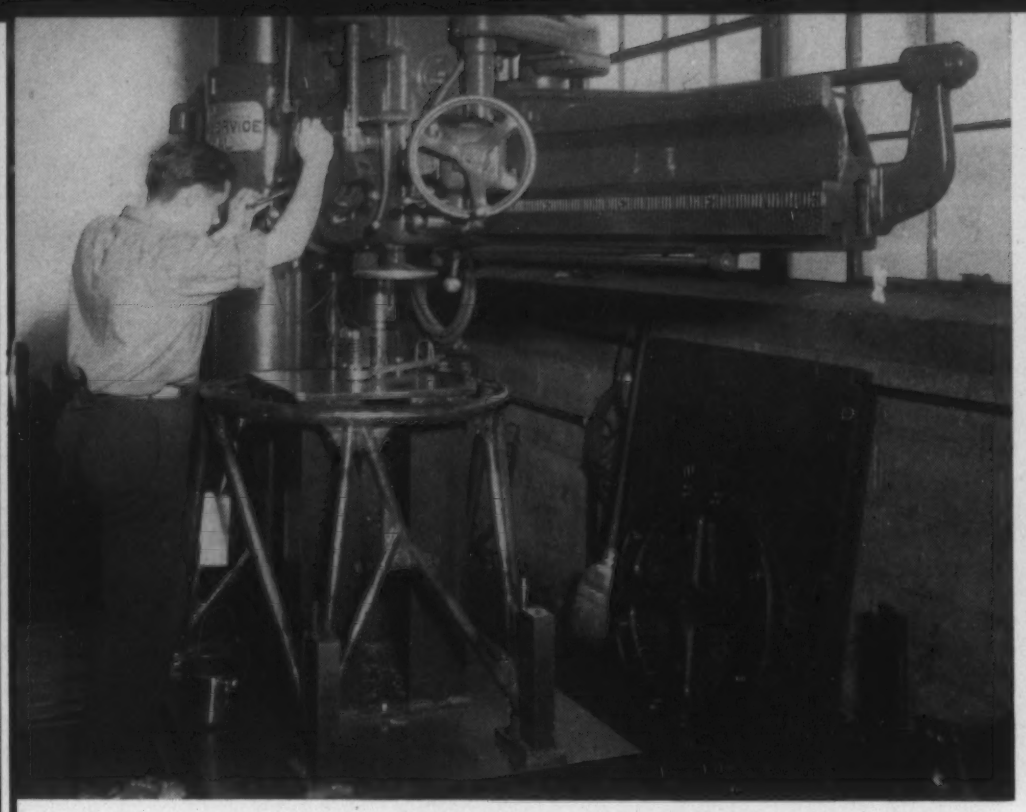
assembly but, as the welding causes the tube to contract slightly, it is placed in a flat stretching jig. This is provided with spoke-like members consisting essentially of tubes into which bolts are threaded, so that the length of the strut is easily varied. These "spokes" contact with a circular boss or "hub" at the center of the jig and are lengthened as may be required to stretch the annular tube and insure that the holes through the lugs come at correct radial distance from the center.

Rings thus completed are passed to the main assembly jig in which the ring is assembled by tack welding to legs, gussets and braces. Other joints, such as those where Y-braces join and where legs and braces are joined to the sockets at the fuselage end of the assembly, are also tack welded. In this main assembly jig there are clamps to hold each of the tubes in correct position while they are tack welded together and the gussets are tack welded in place. The jig is used, of course, not only to position the respective units, taken from adjacent tote boxes, but to insure that the dimensions of the final assembly will come within required dimensional limits.

Final Welding

Assemblies which have been tack welded in the manner indicated are then ready for final welding for which several welding stands are provided so that as many different welders can work simultaneously as there are stands. Each stand has a flat circular plate located in a vertical plane and pivoted so that it can be rotated about its center. The annular ring of the tack welded assembly fits against this plate and is fastened to it securely by clamps with pins through each engine mounting boss.

This arrangement has the advantage that the assembly is easily turned by hand about the supporting pivot to bring the joints to be welded into a convenient position for the welders to work to best advantage. It makes it possible for them always to weld "down," that is, with the joint being welded always below the flame, never above it. This is true not only of welds on the outside of the assembly but of those on the inside. To facilitate welding inside joints when these come in desired position at low levels, operators are provided with low stools on which to sit while making these welds. After each weld is made, the operator is required to stamp it with his number so that he can be held



Setup of radial drill with jig for holding the engine mount and for locating the tools which ream and face the engine mounting bosses.

Final machining setup showing the substantial jig used to locate the engine mount and the tools which face and ream the sockets which later join the engine mount to the fuselage of the bomber.

responsible for and make good any defective welds which may be found in later inspection.

Since welding, no matter how carefully done, may result in some distortion of so large an assembly, the latter is tested in a jig and is straightened, if required. Assemblies are then ready for test and inspection. Since the structure is made from tubes which are inter-connected and have only a limited number of holes, it can be and is tested under air pressure after plugging the holes temporarily. When the pressure is applied, the welded joints are covered with a soap solution so that bubbles will form where any joints made by welding may leak. If leaks are discovered, of course, they are stopped by further welding before the assembly is passed to the next operation.

Some Machining Necessary

Welded assemblies are required to come within certain dimensional limits, but it is not feasible to make these as close, at critical points, as is required under the specifications which apply, without doing some machining. In consequence, some extra metal is left for machining at the engine mounting bosses and at the sockets for attachment to the fuselage frame. This machining is done in radial drill setups with jigs and tooling such as to insure the close dimensions specified.

In the first of these setups, the mount is placed in a jig on the base of the radial drill, with the annular ring at the top, as shown in one illustration. A jig plate is placed on the top face, after which the hole through each engine mounting boss is reamed to size and with its center, of course, determined by a bushing in an arm made to swing about the center of the plate. Then the top face of each mounting boss is faced, using an end mill piloted in the reamed hole. Finally, in the same setup, the under face of each boss is faced flat from below, using again an end mill which, in this instance, cuts on its upper face and is piloted, as before, by the reamed hole. It is necessary, of course, to remove this end mill from the driving chuck after each boss is faced and before the spindle of the drill press is swung into position for the next hole. After each boss is thus finished, the assembly is removed and passed to another radial drill.

In this final setup, the engine mount is placed in a jig which locates it with the ring at the bottom and positioned on the bosses machined in the prior operation. This jig also has locating bars which enter the sockets from below and a supplementary jig is placed in the position shown on top of the sockets. This portion of the jig is centered on a pivot carried on a column forming part of the lower jig and carries bushing located at the correct radius to guide the tool which faces and reams each of the sockets at the four corners. By the use of these sturdily built jigs it is possible to hold the height from the engine mounting bosses to the face of the sockets within 0.005 in. of the drawing dimension, even though the over-all dimension of the mount is large and a welded structure of light tubing is used. The jigs also insure holding the radial distances and angular spacing required.

This operation completes a structure which, despite its light weight, is exceedingly strong and rigid and is ready to be assembled to the fuselage of the bomber on the main assembly line in which the fuselage is put together. The production of this mount is an excellent example of welded structure fabrication and is typical of that required for highly stressed elements of a modern Martin bomber.

Heat Treatment of Steel Castings

—Early History

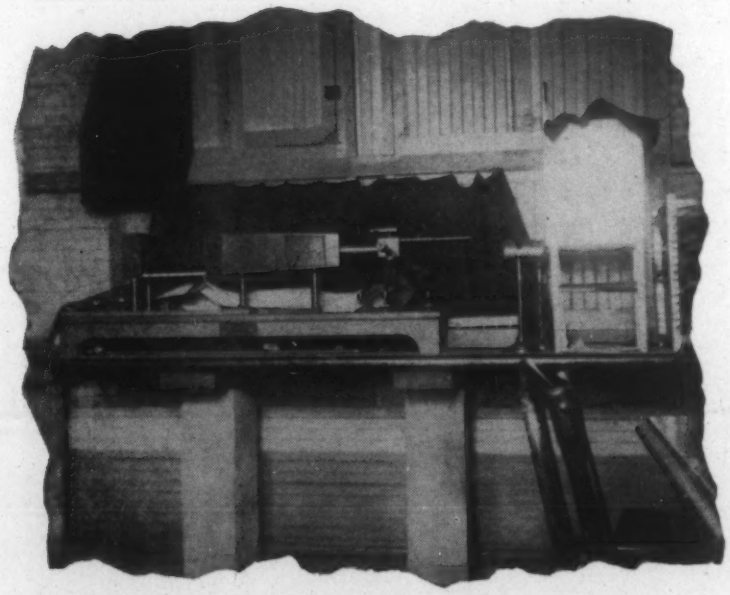
by JOHN HOWE HALL

Consulting Metallurgical Engineer, Chestnut Hill, Philadelphia.

The early days of the heat treatment of steel castings give rise to some interesting history. In the early history of the steel casting industry some strange practices in annealing or heat treatment were carried on. We recall that it was once thought that if a casting were "red" when it came out of an annealer, it was satisfactorily "heat treated"—no attention was paid to the fracture. We recall certain other facts—a casting was pronounced "annealed" if it were allowed to rust over night in the dampness. And such castings passed the inspectors!

Great strides have been made since those days in our knowledge of the proper heat treatment necessary to attain a fine structure. No man is better qualified to recount the history of this development than the author of this article. And it is most interestingly told.—E.F.C.

The author (center) and two of his associates in the metallographic laboratory about 1908.

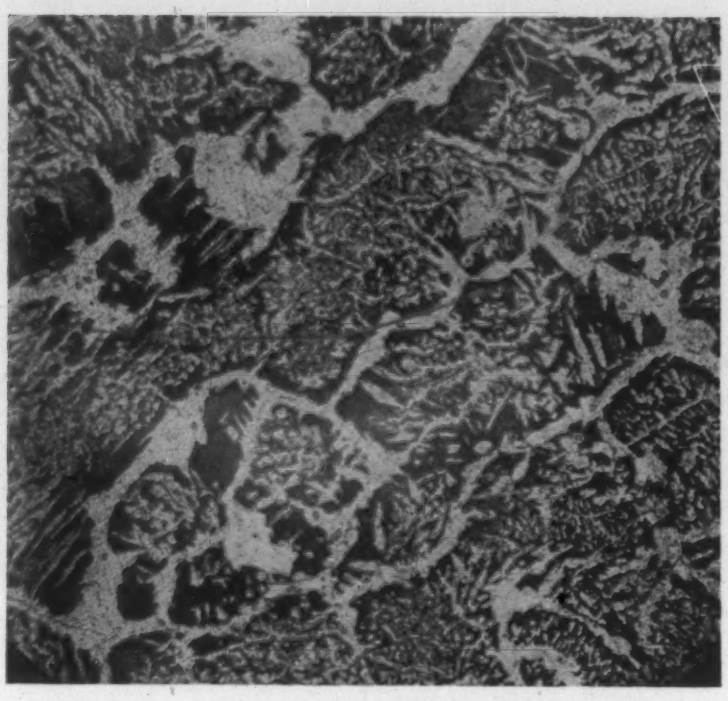


Early type of French made metallographic microscope used in 1908.

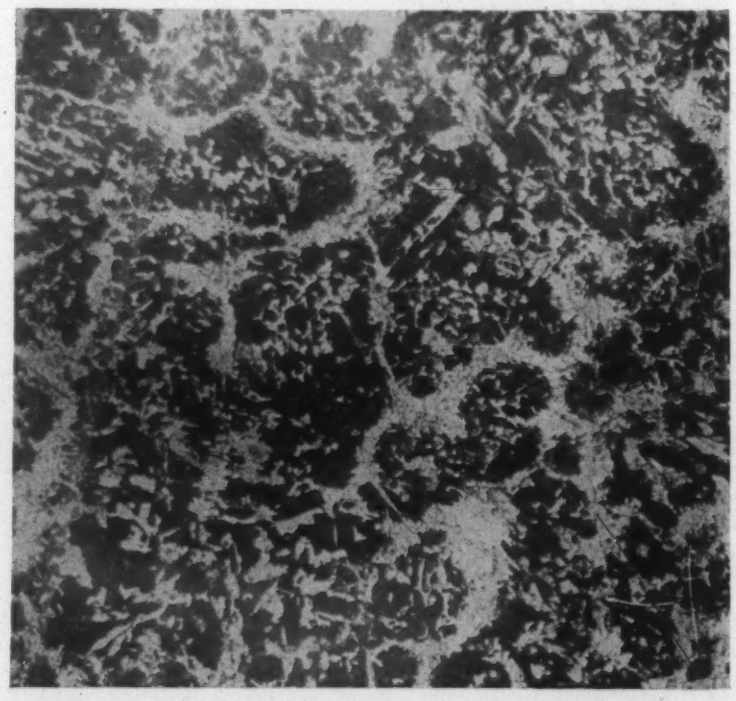
IN THE INTERCHANGE OF NOTES between the silent lovers in H. C. Bunner's immortal "Love Letters of Smith," the swain volunteered the information, "I was one v'yage to Van Diemen's land." To his lady's scribbled reply, "That must have been very interesting," came the laconic response, "It worn't." Something the same thought comes to my mind when I recall our instruction in the metallography and heat treatment of cast steel, in the early days of the present century.

Fred McIntosh, Arnold Jackson, Bill Meade, and a few others, sat with the author at the feet of Albert Sauveur, pupil and friend of Howe, and later his successor as the leading metallurgist of the country. Most of the work on the microstructure and heat treatment of steel, up to that time, had been carried out on rolled or hammered material, and it was not yet even suspected that the metal in the cast state might react differently to heat treatment.

Accordingly, we were taught that in the cast state, ordinary steel has a coarse microstructure of ferrite and pearlite, and we were shown etched samples and photomicrographs that correctly represented the untreated metal. To refine this structure, we were told, required simply a short heating above the critical temperature range, and a slow cooling in the furnace. The steel should then show a finely divided pearlite-ferrite structure, exactly the same as that of a previously over-heated piece of rolled steel of similar carbon, after such an anneal. The structure of the cast metal, indeed, was considered to be closely similar to that of rolled steel heated to some 1100 or



Structure of cast steel (0.43% C.) as cast.



Structure of cast steel (0.42% C.) annealed at 900 deg. C., slow cooled to 800 deg. C. and quenched.

1150 deg. C., and it was supposed to respond similarly to simple annealing.

Therefore, several two-man squads of earnest pupils, after polishing, etching and examining the structure of samples of as-cast steel furnished in the laboratory, proceeded to give their specimens the prescribed heating to 900 deg. C., followed by a furnace cool. To our disgust, the annealed specimens, though considerably changed in microstructure from that of the raw steel, still showed abundant traces of the primary ferrite, and nowhere was the structure fine, like that of the well-behaved rolled material. After a peek through the microscope, the verdict of the Professor was immediate and laconic, "You did not heat those pieces above the critical temperature range." Back to the laboratory to repeat the experiment went the obedient squads, to secure the same unsatisfactory result a second time, with the same verdict on our work. We passed on to the next item on the program of the course, with a poor mark for the cast steel experiment, and a lurking suspicion that there was a sour note somewhere.

The next year, while I was laboring as a graduate student, making some of the earliest melts of vanadium steel that were produced in this country, the metallography class consisted of a group under the inspiration of Ken Lewis, whose motto proved to be, "Show us, we're from Missouri." Remembering the experience of us, their predecessors in "Metallurgy 14—Elementary Metallography," they were out to show or be shown on the cast steel sample, and at least one squad subjected a specimen to no less than 19 successive heatings to 900 deg. C., and coolings in the furnace, with substantially the same microstructure every time. Like Smith's views of the v'yage to Van Diemen's Land, their verdict was finally " 'Tisn't,"—but they had no answer as to how the job should be done, to secure fine microstructure.

On the heels of that, Lewis, Jackson and I went to the Bethlehem Steel Co.'s old Lehigh plant, and while learning to make steel and pounding sand in the foundry, I forgot for the time the vexing question of how to give cast steel a fine microstructure. In fact, beyond listening to my molder friends' explanation that the annealing of steel castings resulted in the elimination of a large part of the carbon, with resulting change from a brittle to a ductile state, and the observation that removing the covers from the old-fashioned pit annealers gave the castings at the top of the heap higher yield points, I cannot recall that I gave the heat treatment of cast steel much thought. Making open-hearth and crucible steel, heating and hammering tool steel bars (it was almost treasonable then to think of rolling them!), making bullet-proof thin shield plates for field guns, and similar matters, occupied all my attention.

There followed an experience as a melter in a crucible steel foundry, where I learned that a terrible epidemic of blowholes that appeared only upon machining the castings was *not* due to gassy steel, but to over-bonded hard-rammed sand mixed by the ex-gray iron foreman in charge of the molding floor. Then, late in 1906, my fate took me to the old Taylor Iron & Steel Co., as metallographist, and back to the heat treatment of cast steel, under the direction of the vice president, the late Henry M. Howe. Then indeed I went on a "v'yage" of discovery, fortunately interesting to a degree, in striking contrast to Smith's Van Diemen's Land trip.

After a few weeks' work in the Columbia University laboratories, under the eye of the late William

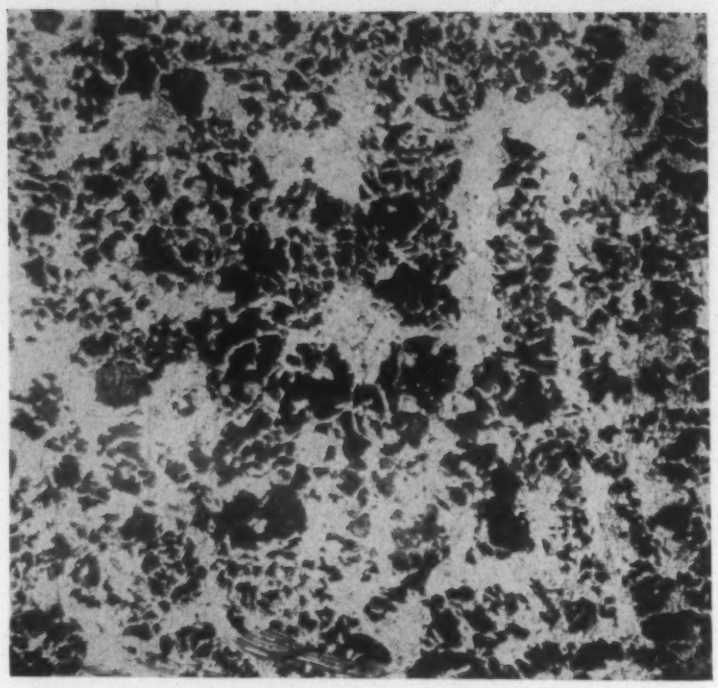
Campbell, as fine a gentleman and as gentle a soul as ever drew the breath of life, I was sent out to High Bridge to go to work in earnest. At Columbia I had solved the (then) tough problem of etching austenitic manganese steel, whose microstructure up to that time had been a closed book, and at the plant laboratory I expected to work out the heat treatment of carbon cast steel in the intervals of investigating and systematizing that of the austenitic material. Had any one told us at the start that we would be two years in solving the problem that we had just bowed to in Sauveur's laboratory, we would have smiled a superior smile—but as it turned out, we did not have the full answer for nearly two years.

Our first work, planned by Howe, and only just looked at by my predecessor as metallographist at High Bridge, was to secure pieces ½ in. cube, from ½ in. square cast steel bars, and from the outside corners and the centers of 6 in. square coupons from the same heats. In each size we poured samples from a heat of 0.25 per cent carbon, one of 0.40 per cent carbon, and one of 0.55 per cent carbon steel. These pellets, wired together in sets of nine, were heated for ½ hr., 1 hr. and 2 hrs. to different temperatures, and cooled in a box of lime, to secure "slow" cooling. After one or two hours heating at 900 deg. C., the pieces cooled in the lime box showed the expected finely divided ferrite-pearlite microstructure, and our problem appeared to be solved.

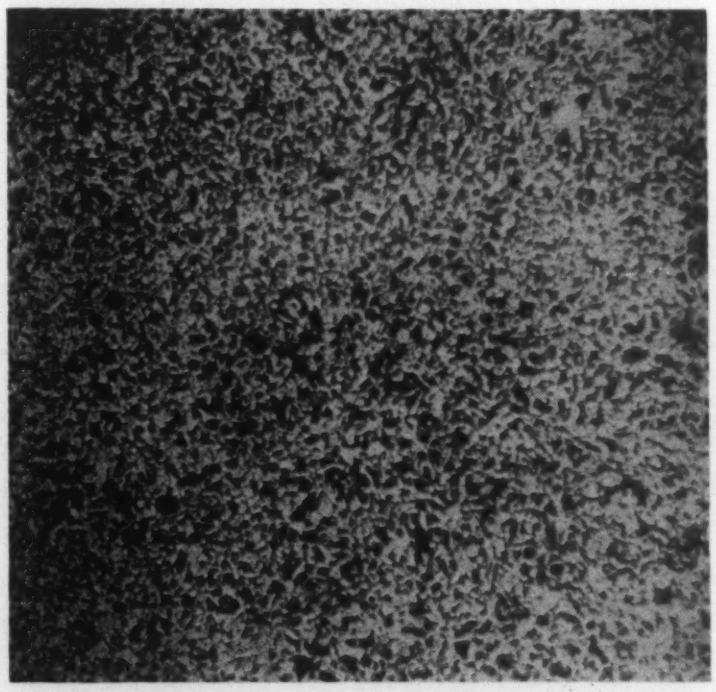
Castings were then ordered annealed at 900 deg. C., for from 2 to 4 hrs., followed by cooling in the furnaces, and coupons cut from them were sent to the laboratory for examination and test. To our disgust, they showed the coarse microstructure, with abundant traces of primary ferrite, that we had seen in Sauveur's laboratory some years before.

At first, of course, our verdict was the same as Sauveur's, that the castings had not been heated to the temperatures reported. Personal observation of the heating of a few annealing furnace charges soon disposed of this contention, and we were back where Lewis left the problem, after he proved that 19 heatings and slow coolings did not give the desired structure. Naturally, by now we were beginning to see that there was a strong probability that slow cooling produced the undesirable microstructure in cast steel, although for rolled material it was satisfactory. Experiments to ascertain the truth of this postulate were immediately undertaken.

By heating cast steel bars to 900 deg. C. for the proper length of time in the laboratory furnace, and cooling them in air blast, in still air, in lime and in the furnace, we soon found that only the bars cooled slowly in the furnace had the coarse structure, somewhat resembling that of as-cast material, which we had obtained by annealing and slow cooling in furnaces of commercial size. A set of bars annealed at 900 deg. C., cooled slowly to different temperatures,



Structure of cast steel (0.41% C.) annealed at 900 deg. C., slow cooled.



Structure of cast steel (0.41% C.) annealed at 900 deg. C., cooled in 40 min.

and quenched in water to fix the existing structure, showed that the coarse structure appeared upon cooling to some temperature between 800 and 750 deg. C. —in other words, free ferrite was liberated on cooling past Ar_3 into the critical temperature range. We soon learned that if cooling from 900 deg. C. to black heat took place in 20 min. or slightly over, a fine net-work microstructure resulted, while a slower cooling rate gave rise to the coarse structure. In small pieces, cooling in the air blast produced large lakes of sorbite almost entirely free from ferrite dots as seen under low magnifications, in a background of fine ferrite-pearlite net-work structure, while in specimens cooled in still air, only the latter was present.

At about this stage of the proceedings, test specimens were sent to Professor Campbell at Columbia, who soon proved to his own satisfaction that annealing cast steel at 900 deg. C., followed by "slow cooling" gave satisfactory fine microstructure. His conclusions, which were published somewhat later in a paper before the American Society for Testing Materials[1] were briefly that "Cast Steel is completely refined by heating a little over Ac_{2-3}, except when there is a net-work of manganese sulphide or slag globules present—in which case some traces of ferrite remain." The temperature he found necessary for complete refining was 855 deg. C. The photomicrographs he exhibited in proof of this conclusion show plainly that his samples had cooled at a comparatively rapid rate. When, some years after this, he put on Uncle Sam's uniform and served at the Brooklyn Navy Yard on plant-scale furnaces, he saw he had been deceived by the too-rapid cooling rate of his small laboratory furnace, which gave fine structure in the cast specimens, just as did our own lime-box cooling of nine ½ in. cubes wired together. Professod Campbell's standing, of course, was such that his conclusions, erroneous as they proved to be, were a thorn in my side for several months.

In view of some of the more recent researches on the heat treatment of cast steel, such as those of Merten and of Fletcher Harper, in which a preliminary annealing at a comparatively high temperature was recommended for heavy castings, it is interesting to note that not long before Campbell conducted this research, he cooperated with Howe and Koken in work to determine at what temperature the "ingotism" of cast steel could be eliminated. Their conclusions[2] were that at temperatures of 1180 to 1194 deg. C., ingotism is rapidly eliminated. The attempt, now known to have been unsuccessful, of later investigators to utilize these high temperatures to anneal castings of very heavy section, and completely refine their microstructures, thus had its origin in this early work of Howe and Campbell.

It seemed clear from our own work, despite Campbell's findings, that only when the cooling took place in less than ½ hr. could satisfactory microstructure be expected. For castings not to be subjected to very severe service, and of such size that groups of them could be made up so that they would cool in approximately ½ hr., we adopted a single anneal, similar to the plain normalizing often practiced today. However, at that time we were most interested in steel containing from 0.40 to 0.55 per cent C, and many of the castings were of such size and shape that they cooled comparatively rapidly. The result, of course, was that the elongation and reduction of area of these castings were lower than we considered desirable, and a drawing or tempering treatment after the air cool was necessary to give proper toughness. It seems strange today, but Howe laid it down as fundamental that this "draw" must be at a temperature above Ac_1, since only by heating above that temperature, he thought, could re-arrangement of the microstructure and the desired improvement of ductility be secured. And here the train went into the ditch with a vengeance!

Had we examined our results more closely and with an open mind, we might have been spared much trouble and endless work, for the answer was there in our first efforts for anyone to see. Bars annealed at 900 deg. C., and either quenched or air-cooled, were reheated to various temperatures from 500 to 750 deg. C., and satisfactory fine microstructures were secured in those heated to temperatures not exceeding 700 deg. C. At 750 deg. C., signs of free ferrite began to appear—but again the bug-a-boo of insufficient heating at 900 deg. C. was raised to account for this result, so that attention was diverted from the real cause.

Our mechanical properties, too, were rather erratic, making it difficult at times to properly interpret our data. This was because the "keel-block" type of coupon for cast steel had not then been invented, and our test bars were at first cut from longitudinal sections of bars cast on end, 4 in. square by 12 in. long, one quarter being used for an "as-cast" test bar, and succeeding quarters being used for testing after the anneal.

These bars varied in a disconcerting way in elongation and reduction of area, and so did independently cast test pieces of various cross-sections. Keeping in mind the then still accepted view that over-heated rolled steel would behave in heat treatment exactly the same as the cast product, Howe then directed us to pour a number of ingots from one of our casting heats, and have them rolled to 1-in. round bars. The rolling was done for us at the Carpenter Steel Works in Reading, Pa. These bars, of course, were free from the variations in mechanical properties that had plagued us with our early cast steel bars, and by heating them to 1150 deg. C., or so, we gave them a "plenty coarse" microstructure.

These "overheated rolled bars" were now substituted for as-cast material, and it was found that annealing at 900 deg. C., air cooling, and reheating at 740 deg. C. resulted in a perfect, finely divided ferrite-pearlite structure. When cast specimens similarly treated in the laboratory furnaces showed free ferrite masses in a fine ferrite-pearlite background, after reheating at 750 deg. C., and only a fine structure if the reheating were at 700 deg. C., I was still told that the first heating was at fault. The work of Howe, Campbell and Koken was recalled, and I was directed to anneal "overheated rolled bars" at 940, 980 and 1000 deg. C.., air cool, and reheat to 750 deg. C. Satisfactory microstructures resulted. It was further found that in order to properly refine the net-work structure set up in "overheated rolled

bars" by air cooling from 900 deg. C., a temperature of at least 740 deg. C. was required. Temperatures of 700, 710, 720 and 730 deg. C. did not produce refining; 740 or over did, though there was a rapid increase of the grain size when temperatures as high as 780 deg. C. were employed.

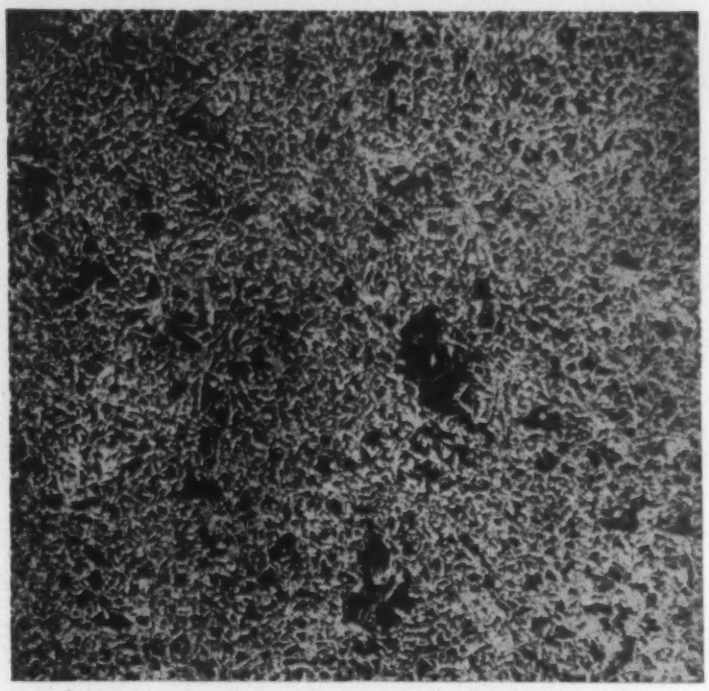
It was also suggested that the liberation of free ferrite in cast steel on reheating the air-cooled material to 750 deg. C., might be caused by slow heating to and cooling from that temperature, too long holding, or what not. Rapid coolings from the draw, however, did not give the expected results, short holdings did not give sufficient ductility, and it was decided to rely entirely upon the conclusions derived from the tests on "overheated rolled bars."

Incidentally, an attempt was made to refine the structure of the "overheated rolled bars" by annealing for several hours at 880 deg. C., and cooling slowly in the furnace, à la Campbell. The structure was not properly refined, contrary to Campbell's findings in the case of cast steel, abundant traces remaining of the coarse structure of the overheated steel.

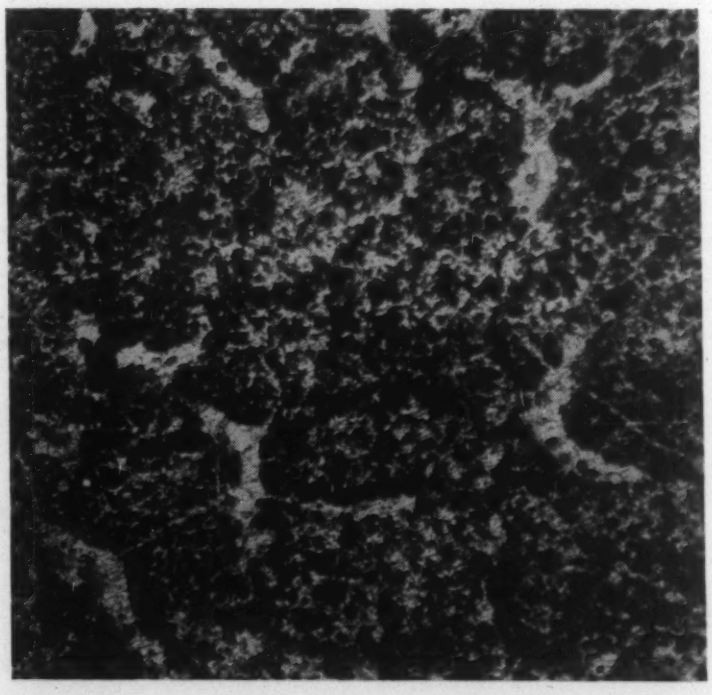
Relying, to our sorrow, upon the results secured on the "overheated rolled bars," the annealing furnaces in which our castings were being handled were put on a schedule involving holding for 4 hrs. at 900 deg. C. after the castings were at that temperature, air cooling by removing the castings from the furnace, reheating to 760 deg. C., for several hours, and then cooling slowly in the furnace. On each of the castings to which a coupon was attached we placed an "overheated rolled bar," whose structure was to be a guide to correct heat treatment.

The mechanical properties of cast coupons attached by their long dimension to places on the drag side of comparatively heavy castings, we had now found to be comparatively free from the variations we had experienced with our 4-in. square separately cast bars. so that we had a reliable test for the properties of the castings, to compare to that of the "overheated rolled bars."

When we had examined and tested a few furnace charges of castings under the new schedule, we found that most of the overheated rolled bars treated at 900 and 760 deg. C. showed complete refinement of the microstructure, but a very large number of the cast coupons exhibited large or small masses of free ferrite in a background of refined structure, and were somewhat deficient in ductility. In cases where the microstructure of the cast coupons was free from these ferrite "lakes" and resembled Campbell's one-heat "completely refined" structure, ductility was generally satisfactory; the accompanying "overheated rolled bars" were then in almost all cases found to be improperly refined. Of course, this indicated that there were considerable variations in the draw temperature in different parts of the furnace, which in



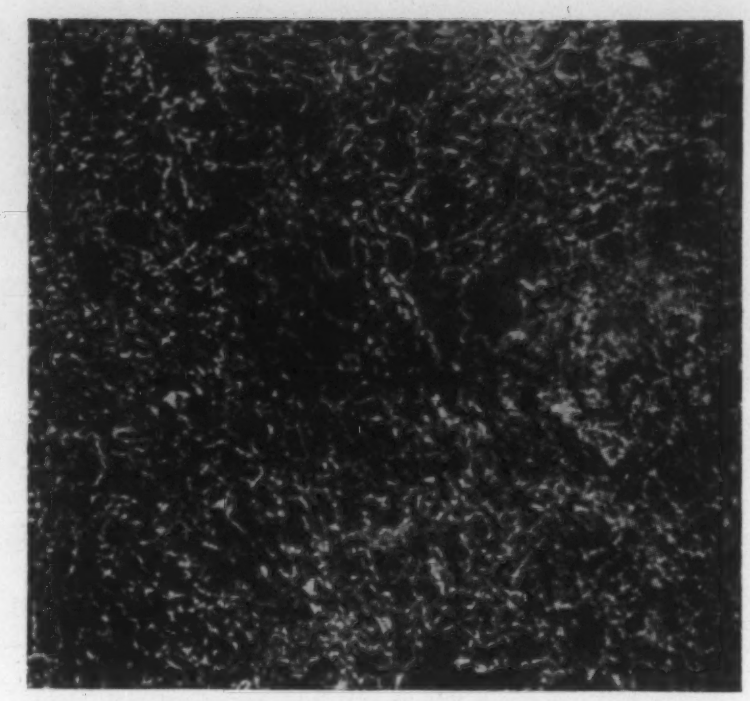
Structure of cast steel (0.43% C.), annealed at 900 deg. C., cooled in 10 min.



Structure of cast steel (0.59% C.), annealed at 900 deg. C., air cooled, reheated to 760 deg. C. and slow cooled.

the rather crude coal-fired furnaces of that day was not to be wondered at.

In a last lingering effort to ascribe this free ferrite in the cast steel to insufficient heating at 900 deg. C., resulting in "remanent" rather than "re-nascent" ferrite, experiments at the high temperatures suggested by Howe, Campbell and Koken were renewed. A number of specimens of cast steel were annealed at 1000 deg. C., for periods up to 7 hrs., and cooled in air. This gave a microstructure not much coarser than what we secured on air cooling from 900 deg. C., but containing some areas of sorbite with little



Structure of cast steel (0.50% C.), annealed at 900 deg. C., air cooled, reheated to 700 deg. C., and slow cooled.

or no free ferrite, like those in samples cooled from 900 deg. C. in an air blast. Upon reheating these specimens at 760 deg. C., however, the undesired areas of free ferrite promptly reappeared, the structure being but little different from that of the pieces heated to 900 and 760 deg. C. If there were anything in the idea, recently advanced, that heating to high temperature results in more completely breaking up the original cast structure, we should not have had this immediate and complete reappearance of the ferrite "lakes" on heating above Ac_1—but we did.

When the investigation had reached this point, with the main problem, that of securing fine microstructure and maximum mechanical properties still unsolved, the management of the company showed signs of losing faith in our ability to reach a successful conclusion of our work, and on a long evening walk with the active manager, the late Knox Taylor, I was told that if I did not get the investigation cleared up in a short time, the metallographic department would be abolished as a failure, and my job naturally would go with it. Though our success in improving the heat treatment of austenitic manganese steel, and other shop processes, had been so outstanding that I did not really credit this veiled threat at its full worth, still naturally it put me on my mettle, and the investigation from that time went under forced draft, with fire flying from the top of the stacks, so to speak.

To disprove the theory, to which Howe still seemed inclined to hold, that the free ferrite we were striving to eliminate was remanent, I compared and tabulated the physical properties and microstructures of over 700 cast coupons and "overheated rolled bars." My conclusion was that the way to eliminate the undesirable free ferrite "lakes" which corresponded with low ductility, was to lower the temperature of the draw to below Ac_1, rather than raise the temperature and prolong the time of the first anneal. The tabulation had shown that the elongation and reduction of area of the cast steel were uniformly lower when free ferrite was present than in the bars that had uniform fine microstructure, and as aforesaid, that these ferrite "lakes" usually were found in cast coupons accompanying perfectly refined "overheated rolled bars." To prove definitely that the draw temperature should be below Ac_1, we resorted to the old reliable "Metcalf" bar. After air cooling from 900 deg. C., a test bar was reheated to 760 deg. C. at one end, the heat tapering off to perhaps 400 deg. C. at the other. The hotter end showed the undesirable free ferrite, "lake" structure, while in parts of the bar that could not possibly have been heated above Ac_1, the long-sought fine microstructure was found.

On Sept. 17, 1908, I recommended that the heat treatment schedule should be heating to 900 deg. C., air cooling, and reheating for 3 hrs. to 700-725 deg. C., followed by air cooling, and then started in to prove to our still somewhat skeptical consulting metallurgist and vice president that I had the right answer. Cast bars air cooled from 900 deg. C. were reheated to various temperatures from 700 to 760 deg. C., and it was soon found that heating above Ac_1 for more than a very few minutes resulted in the liberation of free ferrite and lowered ductility, while heating at 700 or 720 deg. C. gave satisfactory structure and properties. To prevent heating in practice to undesirably high temperatures, in the hotter parts of our old annealers, we now made this temperature 680 to 700 deg. C. Our castings were now found to have the desired fine microstructure and correspondingly high ductility. Their properties have been described in other papers published in the technical press.

With the idea in mind that impurities, as stated by Campbell, might be the underlying cause of the persistent reappearance of ferrite in coarse masses upon cooling slowly from 900 deg. C. into the critical temperature range, or reheating the rapidly cooled steel into that range, we next obtained samples of basic electric furnace cast steel, with very low phosphorus and sulphur content. There were no electric furnaces in American foundries at that time, and our samples were obtained from France, and were so attached to heavier castings as to eliminate irregularities in mechanical properties. This steel was found to behave in heat treatment the same as the bottom blown converter steel we had been working with, so that we were forced to the conclusion that, at least within practicable ranges of chemical

composition, we must accept the results we had secured as normal.

That the draw temperatures we found gave normalized "overheated rolled bars" a fine microstructure, resulted in the reappearance of free ferrite in the normalized and drawn cast steel, and that a draw temperature that gave the best structure in the normalized cast steel, was insufficient to refine the structure of the normalized "overheated rolled bars," seemed at the time a strange result. Nevertheless, it was a fact, and as I was working for a man who demanded absolute proof at each step of an investigation, it was proved several times over.

That we should have decided to adopt air rather than slow cooling, following the draw heat on our castings, as described above, was less abrupt than it sounds in this description. Howe had devised a test piece to measure roughly the remanent stresses in cast steel after various treatments, which has been described in the author's book on "The Steel Foundry." By means of that test piece, we had learned that there are large remanent stresses in cast steel before any heat treatment, even when the bar was cooled in the mold, rather than being shaken out of the sand and cooled in air. After slow cooling from an anneal at 900 deg. C., the stresses, as well as we could measure them with this test piece and a micrometer scale, had been reduced to zero. The same thing was found for the normalized material—there was of course a large stress in the normalized piece before the draw, but after heating at 700 deg. C., especially when this temperature was held for several hours, the stress had again been reduced to zero. Slowly cooled after the draw, there was no stress we could measure, and even after air cooling from the draw heat, the stress was so slight, if existent, that we felt we could afford to disregard it.

Not satisfied to adopt this conclusion simply from the results of tests on a small test piece, we checked ourselves with similar tests on large castings put through the process we had adopted. After the heat treatment was completed, we marked rows of prick punch holes in parts of the castings where tests before heat treatment had shown large stresses were present. Sawing through between these prick punch marks, and measuring their distance apart with a micrometer scale before and after sawing, naturally gave the amount of motion, if any, due to the relief of stresses on cutting through the stressed area. Before any heat treatment, or after normalizing, we found easily measurable amounts of motion due to stress. After slow cooling from 900 deg., motion was absent, and the same was true of castings normalized at 900 deg. and reheated for several hours at about 700 deg. Air cooling after this heating resulted in so little motion, if any, as to be negligible, and it was concluded that it was not necessary to incur the delay incident to slow cooling after the draw, but that immediate air cooling was all right. The same was true of castings reheated after oil or water quenching, as will now be mentioned.

Believing that oil or water quenching followed by a suitable draw might give even better properties than normalizing and drawing did, we then initiated experiments along that line. The conservative metallurgical view of 1908 was that to talk of quenching a steel casting of any sort was pretty clear proof of insanity, and I recall with gratitude the support I received from the then superintendent at High Bridge, M. F. Apgar. I believe it to be a fact that the first steel casting of considerable size to be heat treated by quenching and drawing, was a gold dredge bucket that "M. F." and I put through that process. I can still hear the late Maunsel White's high-pitched voice, when his opinion of the practicability of our scheme was asked,—"The boy's just plain crazy, Howe!"

Immediately we encountered another strange thing. Temperatures that were all right for drawing normalized cast steel, gave renascent ferrite, in "lakes," in the oil or water-quenched material. We were forced to lower the draw temperature to a range of 640 to 680 deg. C., compensating for the slower refining at this temperature by somewhat prolonging the time of holding.

As we had expected, we secured higher strength and especially higher yield point by oil or water quenching and drawing than by normalizing and drawing, with equal or superior ductility as measured by elongation and reduction of area, and especially we secured better impact strength. This treatment was held in reserve as a sort of "ace in the hole," until we tried out the castings of 0.35 to 0.40 per cent C content, for which we had developed the normalizing treatment. These castings were subjected to tremendous stresses in service, and we soon found that it would be necessary to have greater ductility and shock toughness, with as much strength as we had secured in the normalized 0.40 per cent C material. Accordingly, we shifted our production to the 0.25 per cent C, 1.25 per cent Mn steel, quenched in water and drawn, which has been described by the author and others in numerous publications. Its development for cast products in the spring of 1909, and its application in practice in castings subjected to severe stresses, in June, 1909, is another story.

The author gratefully acknowledges the courtesy of G. R. Hanks, president, Taylor-Wharton Iron & Steel Co., High Bridge, N. J., in extending to him the privilege of consulting the records of this old investigation in the laboratory files of the company at High Bridge.

References

[1] William Campbell. "Heat Treatment of Medium Carbon Steel," *Proc. Am. Soc. Testing Materials*, Vol. 9, 1909, page 370.
[2] Howe, Campbell and Koken. *Proc. Am. Soc. Testing Materials*, Vol. 8, 1908, page 185.

Aluminum Alloy Cylinder Heads

A Pictorial Presentation

A few months ago the Wright Aeronautical Corp. of Paterson, N. J., completed and put in operation a new foundry devoted exclusively to the production of aluminum alloy cylinder heads for aircraft engines for National Defense. It is located at the company's new plant—Plant No. 3—at Fairlawn, N. J. It supplements the main foundry located adjacent to Plant No. 2 in nearby Paterson. The management points out that from 9 to 18 cylinder heads are required to produce a single Wright cyclone engine, depending on the type, and that the establishment of this auxiliary foundry prevents a bottleneck in the manufacture of cylinders. It is also pointed out that Wright Aeronautical organization is the only American aircraft engine manufacturer which maintains its own foundries.

A feature of these castings is the external surface which is covered with cooling fins over 2-in. deep and very closely spaced, "as closely spaced as the teeth in a woman's hair comb." The development of a technique which makes possible the casting of cylinder heads with cooling fins so closely spaced and deep is in itself an accomplishment which is largely responsible for the success of the American-built radial air-cooled engines, says a statement of the company.

This new foundry has all the facilities and equipment necessary for the uninterrupted performance of all operations from the raw material to the finished castings. The following illustrations with captions, furnished by the Curtiss-Wright Corp., tell pictorially the steps in their manufacture.—E.F.C.

Aerial view of the new foundry—Plant No. 3—devoted exclusively to the molding and casting of aluminum alloy cylinder heads for airplane engines.

for Aircraft Engines

This object, resembling a porcupine, is a sand mold for a cylinder head casting in the early stages of manufacture. The molder inserts over 1,500 nails in the thin sections of the sand mold to prevent disintegration or breakage during the pouring of the metal. The practice is a factor which has enabled the Wright company to produce cylinders with cooling fins over 2 in. deep.

The molding sand is fed automatically to the molders and core makers. The mobile hopper on the balcony, which surrounds the molding department, feeds sand through chutes to the molders below.

One of the production lines in the foundry for making the molds for the cylinder heads. To the left are molding machines for making the sand molds. The molds are placed on an automatic conveyor (right) which transfers them through continuous process ovens in which they are baked for 7 hrs.

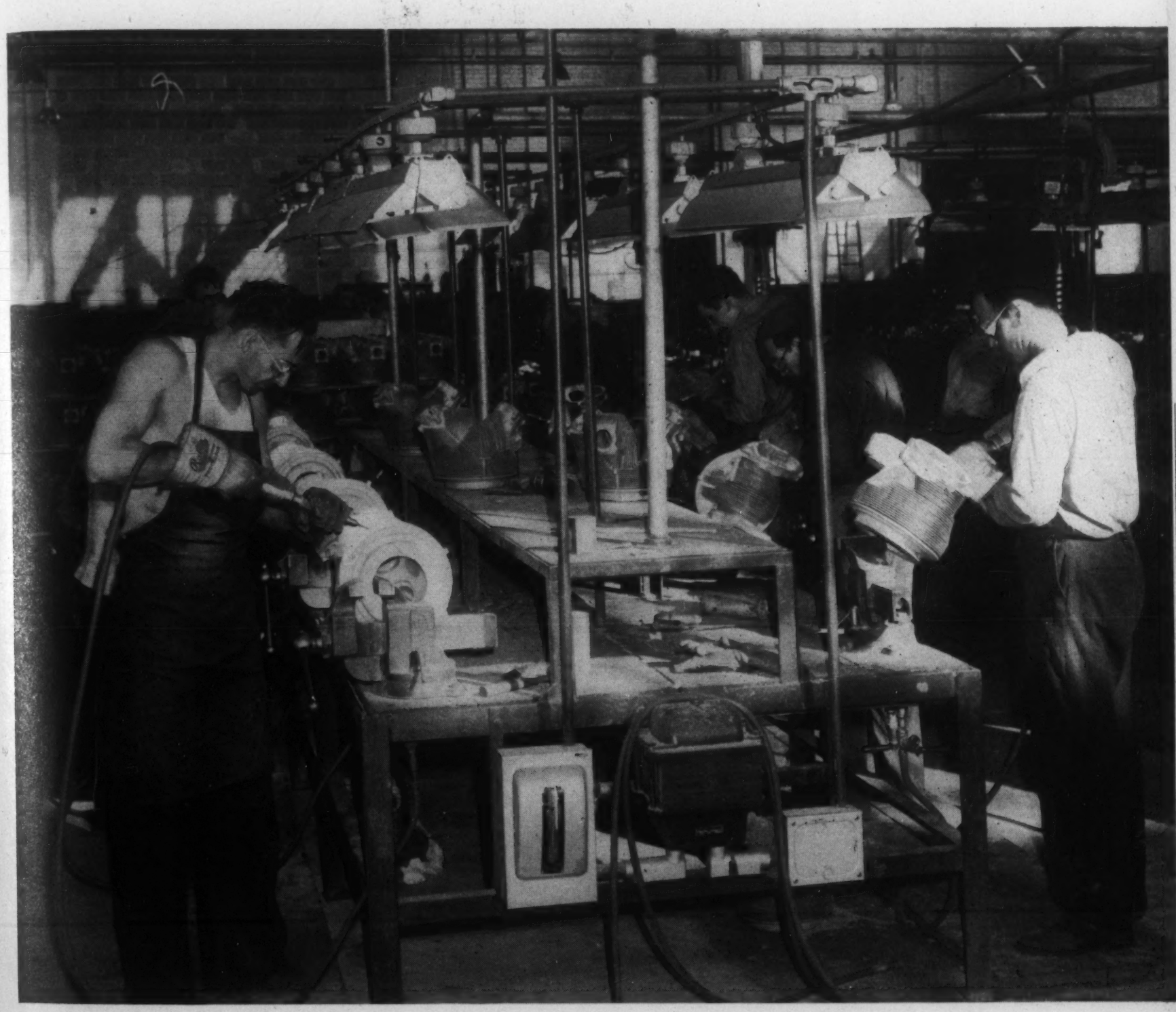
Assembling the halves of the mold and the core for a cylinder head. Into the space between the mold and the core the molten aluminum alloy is poured.

Tapping into a ladle molten aluminum alloy from one of a battery of oil-fired crucible furnaces. The bull ladle of metal, once carried by hand, is transferred by an automatic conveyor from the furnace to the molds.

Pouring the molten aluminum alloy from the bull ladle into the sand molds. The molds move through the foundry on automatic rollers.

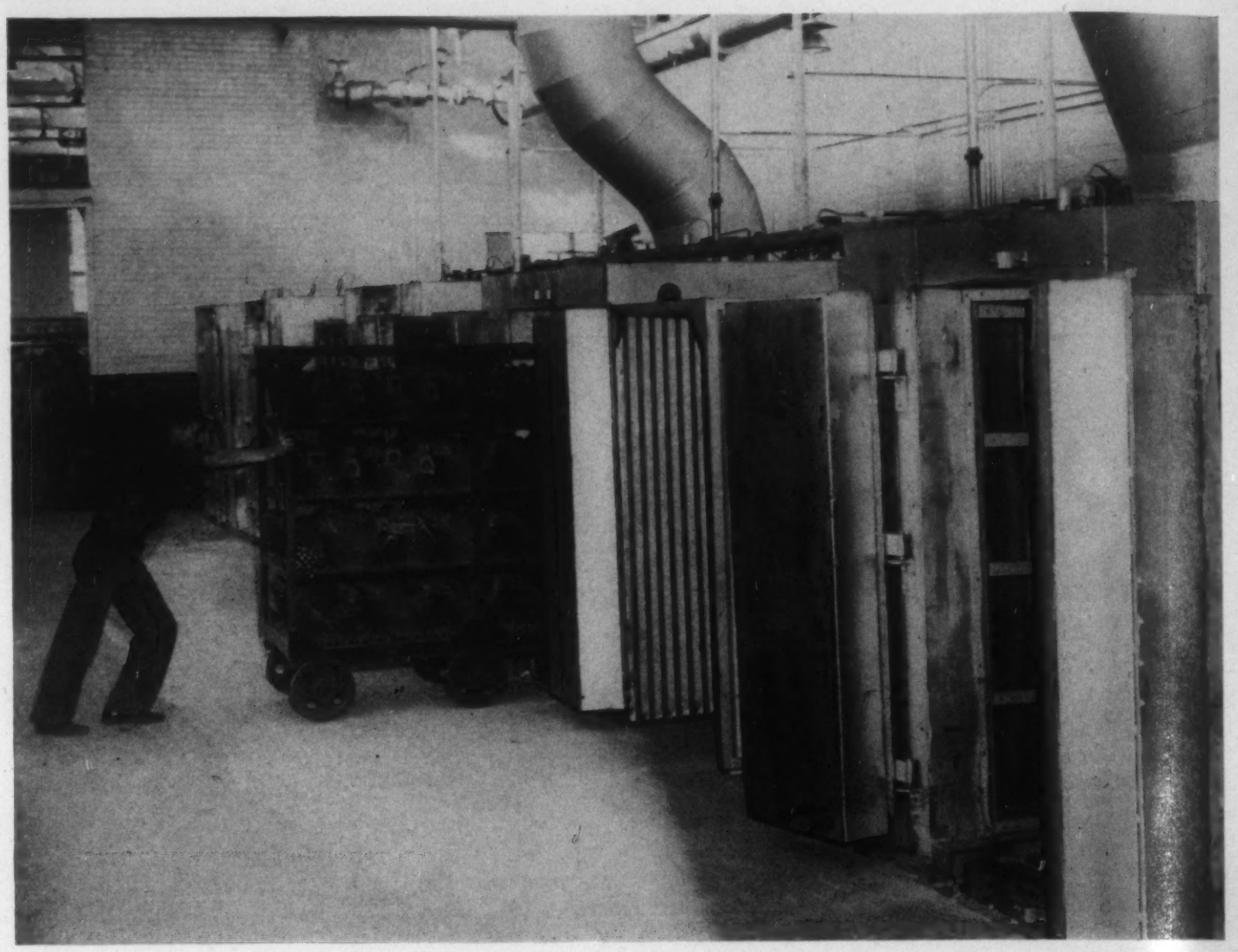
That the foundry production of the cylinder heads is on a mass-production scale is revealed by this illustration.

The sand in the mold and core of the cylinder heads is removed in this line production foundry.



All excess metal is removed or "snagged" from the castings after removal from the molds.

All cylinder head castings are subjected to a heat-treating process—aging. They are here being put into heat-treating furnaces where they are treated at the proper temperature for only a few hours, in contrast to the older method of aging in the air.



All castings receive an identification number.

Tungsten-Copper for Electrical Contacts

—Properties of Various Compositions

by F. R. HENSEL, E. I. LARSEN AND E. F. SWAZY

P. R. Mallory & Co., Inc., Indianapolis, Ind.

ORDINARY METALLURGICAL MEANS do not lend themselves to the production of alloys of copper and tungsten—the two elements are not soluble in each other and do not alloy in any proportion. Powder metallurgy was therefore resorted to as a means of manufacturing compositions of copper and tungsten. Excellent possibilities can be realized from metal bodies formed of combinations of these two metals, particularly for electrical purposes, such as welding electrodes and electrical contacts, due to the physical and chemical properties of the elements. The curves shown in Figs. 1 to 9 give the physical properties which can be developed in such combinations, using various percentages of tungsten and copper.

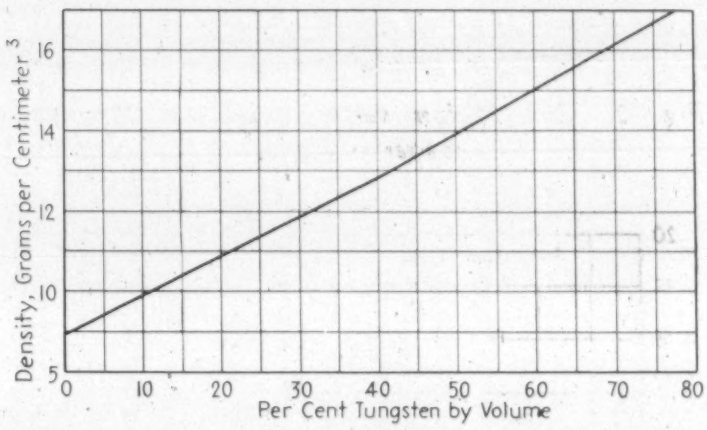


Fig. 1. Composition versus density of tungsten-copper mixtures.

Specific Gravity

To pure tungsten is generally ascribed a specific gravity of 19.1 to 19.3 grams per cubic centimeter. There is considerable variation in the density measurements of powders, rods and wire, particularly if the density is determined on rods which have not been sufficiently worked so as to eliminate all porosity or if WO_3 is present. A value of 19.3 has been adopted for the density of tungsten powder, which agrees with the results obtained with compositions of tungsten-copper. The density of copper is 8.92, which value is in agreement with the most recent density measurements determined by X-ray analyses.

In Fig. 1 and Fig. 2, the effect of composition of tungsten-copper mixtures on the density, expressed either in grams per cubic centimeter or in lbs. per sq. in., is shown. By plotting the density as a function of tungsten in volume per cent, a straight line relationship is obtained. By extrapolating the curve to 0 volume per cent of tungsten, on the one hand, and 100 volume per cent on the other hand, theoretical densities, both of copper and tungsten, are intersected. This indicates that the tungsten-copper mixtures, described in the present paper, have the maximum theoretical density.

Variations in theoretical density which we have found in the practical fabrication of such products, have been very slight, because of the method of fabrication and of a very close control of manufacturing conditions. The most practical range of densities varies from 12 to 16 grams per cubic centimeter. Materials with such densities can be produced in comparatively large and complicated shapes. These mixtures might therefore provide a new structural material of high specific gravity. There are a number of industrial applications, such as fly wheels in gyroscopes, where a concentrated mass, having high strength and resistance to creep, is required.

Expansion Characteristics

Tungsten has a generally accepted coefficient of expansion, over a temperature range of 0 to 600 deg., of 4.6. Values mentioned in the literature vary somewhat, depending on the physical condition of the tungsten used in the measurements. Copper has a coefficient of expansion at 20 deg. C. of

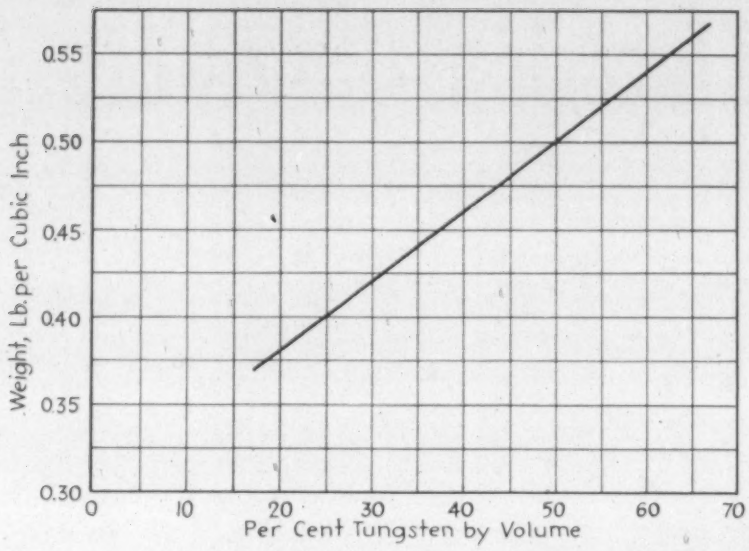


Fig. 2. Composition versus weight of tungsten-copper mixtures.

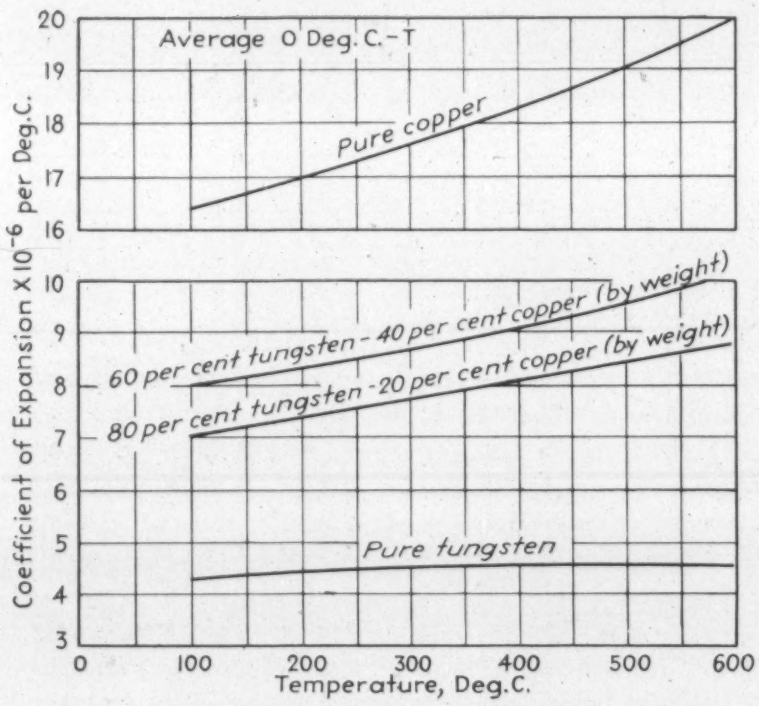


Fig. 3. Coefficient of expansion versus temperature.

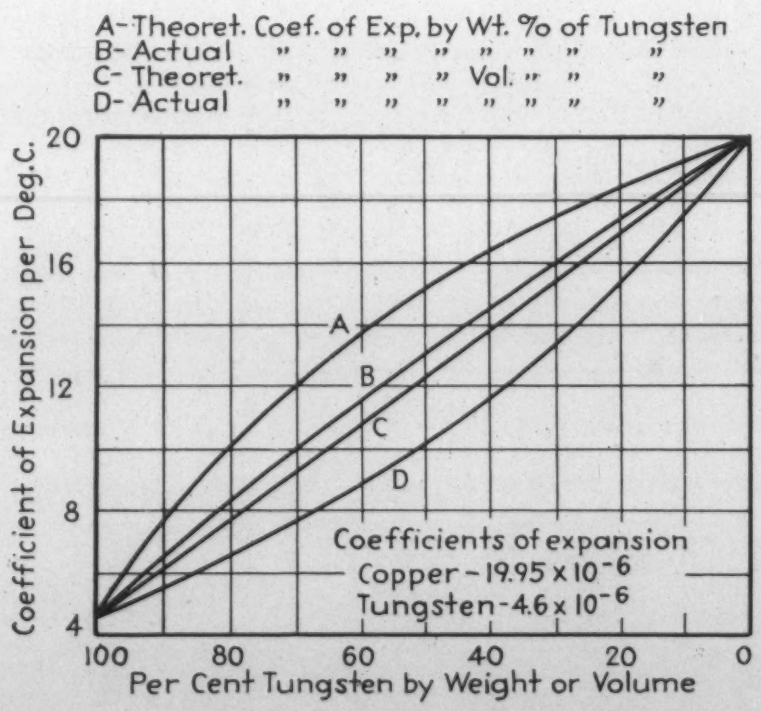


Fig. 4. Coefficient of expansion versus composition by weight of tungsten-copper mixtures through the temperature range of 0 to 600 deg. C.

16.42 x 10^{-6} per deg. C. We have shown in Fig. 3 the coefficient of expansion of pure copper and pure tungsten as a function of temperature. The values given on the curve correspond to the coefficient of expansion, between 0 deg. C. and the respective temperature. In Fig. 3, also, we have plotted the coefficient of expansion of two copper-tungsten mixtures, containing 40 per cent and 20 per cent Cu, respectively. As was to be expected, the compound with the highest tungsten content has the lowest coefficient of expansion.

Since these mixtures of tungsten and copper are not true alloys, it appeared to be of interest to determine the effect of the two elements upon the coefficient of expansion. The results of this study are shown in Fig. 4. In heterogeneous alloys composed of a mixture of crystals of the two constituents, the linear thermal coefficient of expansion is a linear function of the volume concentration. This, of course, is true only as long as no solid solutions are formed and the alloys are free from internal stresses. The theoretical curve of the coefficient of expansion of copper-tungsten mixtures, based on volume per cent, is marked "C"—a straight line. The theoretical coefficient of expansion of mixtures expressed in weight per cent is shown by the curve A.

In order to have a ready means of correlating volume per cent and weight per cent of copper-tungsten mixtures, their inter-relationship was plotted in Fig. 5. The actual values of the coefficient of expansion are also shown in Fig. 4, both expressed in weight per cent and volume per cent. The determinations of the coefficient of expansion were carried out in a hydrogen atmosphere to avoid oxidation of the tungsten. The test specimens were 4 in. long and 1/4-in. in diameter, with a 1/8-in. radius

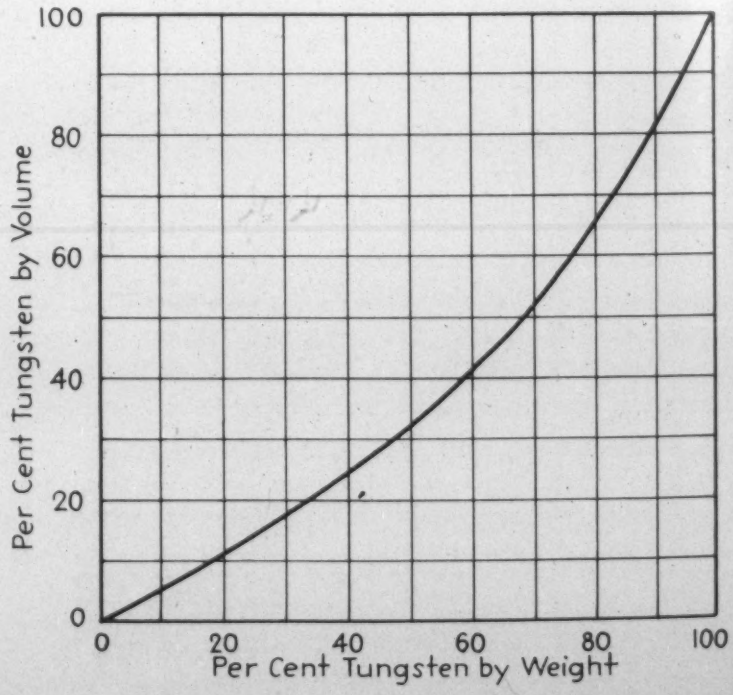


Fig. 5. Relationship of weight and volume per cent in tungsten-copper mixtures. Based on specific gravities of tungsten—19.39 gms. per c.c. and copper—8.93 gms. per c.c.

on each end. It can be seen that the actual values of the coefficient of expansion fall consistently below the theoretical values. The comparatively low coefficients of expansion of copper-tungsten mixtures may be of importance in industrial applications where a material is required which should exhibit the least amount of length or volume changes, due to temperature variations.

The importance of the coefficient of expansion of these materials is emphasized, because in most applications they are applied as facings to backing materials, which may have a considerably different coefficient of expansion and thereby set up stresses in the brazed joint. As a matter of fact, if very thin backing materials of high coefficient of expansion are attached, a bi-metal effect may result, causing considerable distortion.

Hardness

Variation of the Rockwell B hardness as a function of the tungsten-copper concentration is shown in Fig. 6. The increase in hardness with increase in tungsten content can be seen to be very steep. The practical hardness range desirable in commercial tungsten-copper compounds, ranges from 60 to 110 Rockwell B, according to the use to which these materials are put. The hardness values of well prepared material are extremely uniform and consistent. Materials with a hardness of approximately 90 to 100 Rockwell B can be readily machined; however, it is advisable to use carbide tool materials for the machining operation, since standard tool steels wear away very rapidly. This is an indication of the excellent wear resistance of tungsten-copper compound materials.

By using compositions having lower hardness, the tungsten-copper mixtures exhibit good bearing properties and can be used in combination with a softer copper alloy shaft for current carrying bearings.

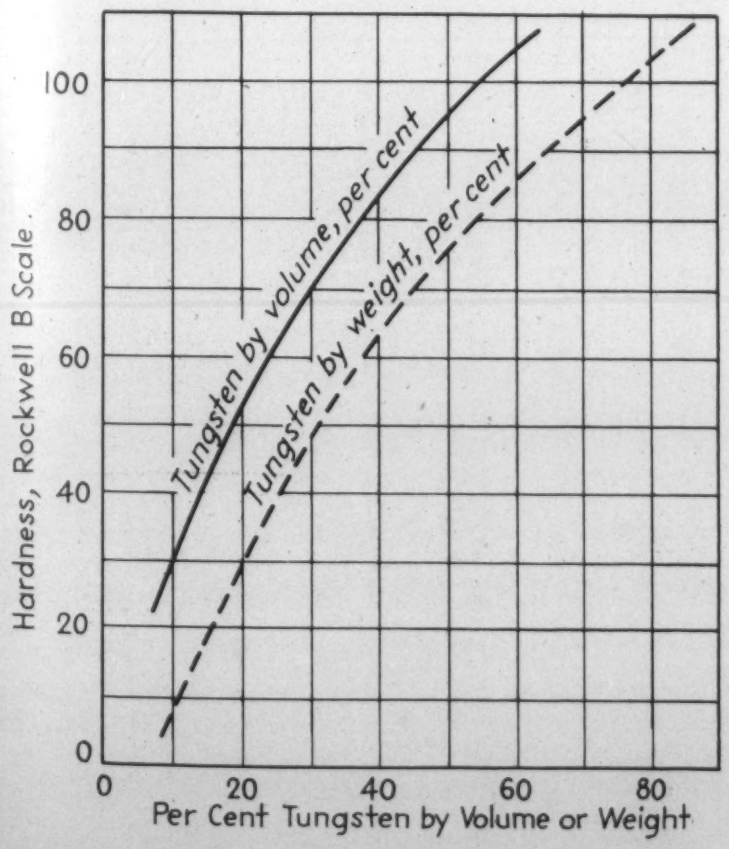


Fig. 6. Hardness versus composition of tungsten-copper mixtures.

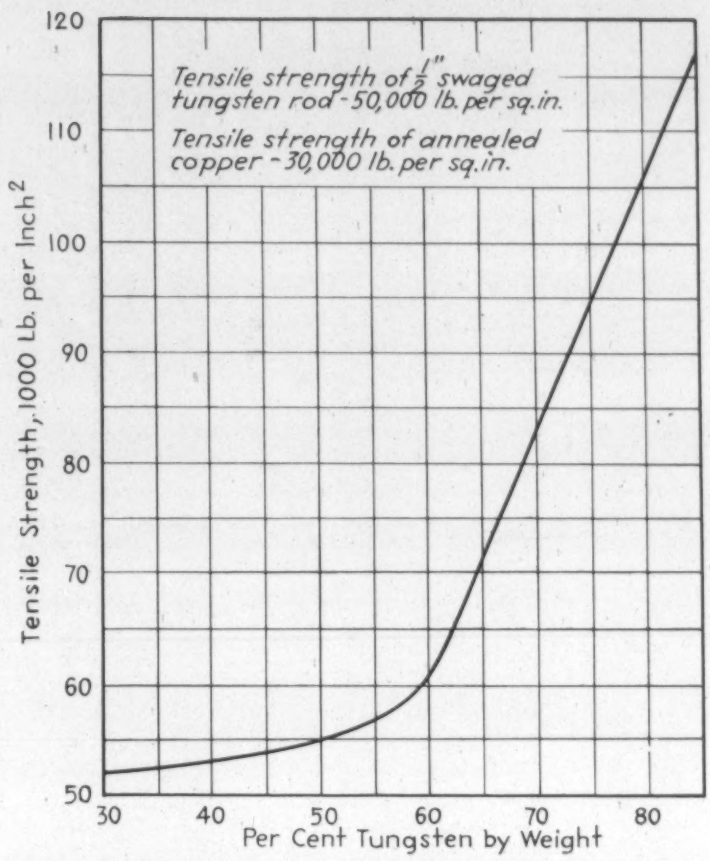


Fig. 7. Tensile strength versus composition of tungsten-copper mixtures. (Test piece, 0.505 in. dia.)

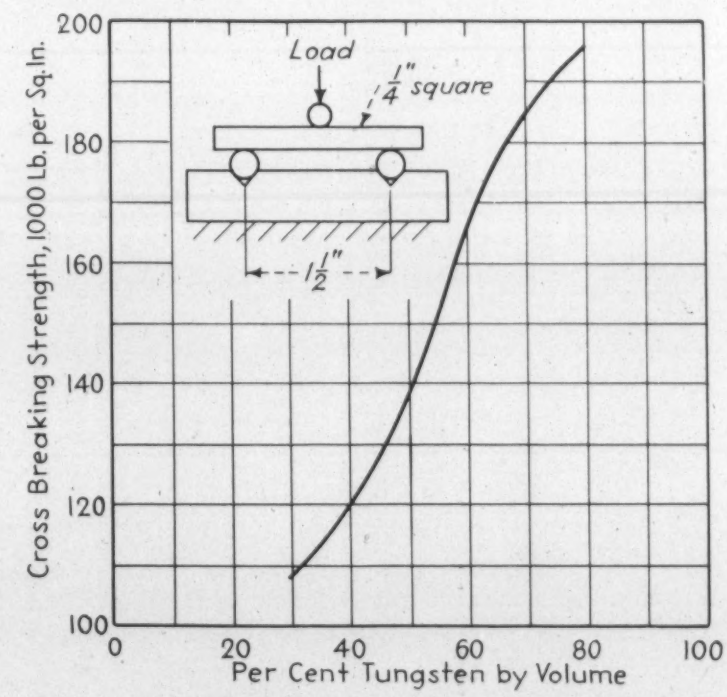


Fig. 8. Cross breaking strength versus composition of tungsten-copper mixtures.

Tensile Properties

In Fig. 7 there is shown the relationship between tensile strength and composition. There is an inflection point in the curve between 50 and 60 per cent of tungsten where the strength increases rather

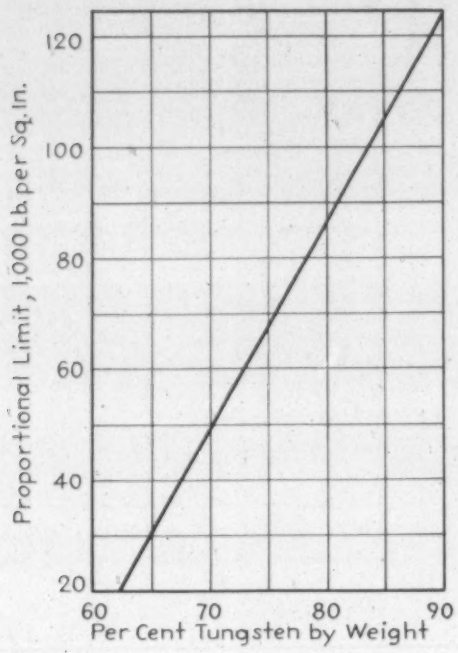


Fig. 9. Compressive proportional limit versus composition of tungsten-copper mixtures.

steeply. The ductility of tungsten-copper mixtures is rather low, particularly in the steep section of the curve. The compositions at the left of the inflection point, where the rise in tensile strength is small, show an appreciable amount of ductility and, when prepared properly, such compositions can be deformed appreciably by cold working without cracking.

We consider it quite remarkable that the tensile strength of annealed tungsten-copper mixtures is considerably above the tensile strength of either pure tungsten rod or copper of equal section—indicating that even though true alloying does not occur, a bonding or wetting takes place during the preparation of the materials which enormously increases adhesion.

The compression strength properties of tungsten-copper compounds are considerably higher than the tensile strengths. A test is generally applied to these materials, which is identified as a "cross breaking" test. The test results shown in Fig. 8 were obtained by placing a ¼-in. square test specimen on two round supports, 1½-in. apart, and applying a load at a point equidistant from the two supports. Note the steepness of the curve indicating the rather large changes in cross breaking strength as a function of small changes in composition. During this test, the ductility of the specimen is determined by measuring the amount of deflection at the stress causing fracture. In general, the deflection decreases slightly with increasing cross breaking strength. The cross breaking strengths of commercial products range from 120,000 to 180,000 lbs. per sq. in.

That the proportional limit in compression is a function of the composition of copper-tungsten mixtures is shown in Fig. 9. Note that the abscissa is plotted on a rather large scale and that within an increase of 25 weight per cent of tungsten, the proportional limit increases by almost 100,000 lbs. per sq. in. Further, it should be pointed out that the compression strength in these materials is considerably higher than the proportional limit; in other words, a considerable amount of yielding takes place before the materials fail. In most cases, the compression strength is 70,000 to 90,000 lbs. per sq.

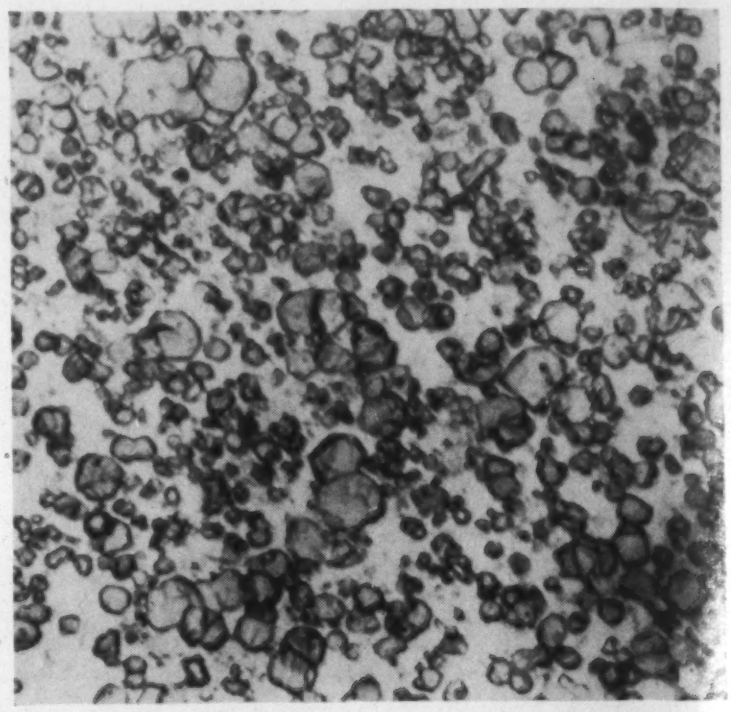


Fig. 10. Structure of a properly prepared tungsten-copper mixture, 1000X. Etchant: For tungsten—3 parts potassium ferricyanide, 1 part sodium hydroxide; for copper—none.

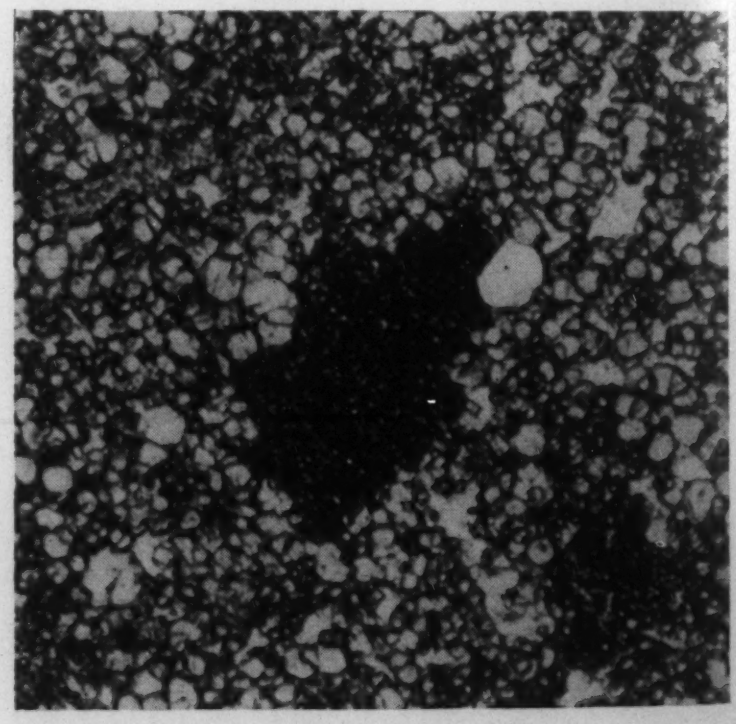


Fig. 11. Structure of an improperly prepared mixture of tungsten-copper of the same composition as Fig. 10, 1000X. Etchant: Same as in Fig. 10.

in. higher than the compression proportional limit. The average compression strength of commercial materials of this type is in the neighborhood of 150,000 to 200,000 lbs. per sq. in. depending upon the composition.

The behavior of these mixtures in compression is quite different from pure tungsten or pure copper, because pure copper has no proportional limit, while in pure tungsten, the proportional limit and the compression strength are pretty nearly the same.

The electrical conductivity of copper-tungsten mixtures can be more or less calculated by the rule of mixtures, provided that no impurities are present. The electrical conductivity of commercial products varies from 25 to 55 per cent I. A. C. S., depending on the composition.

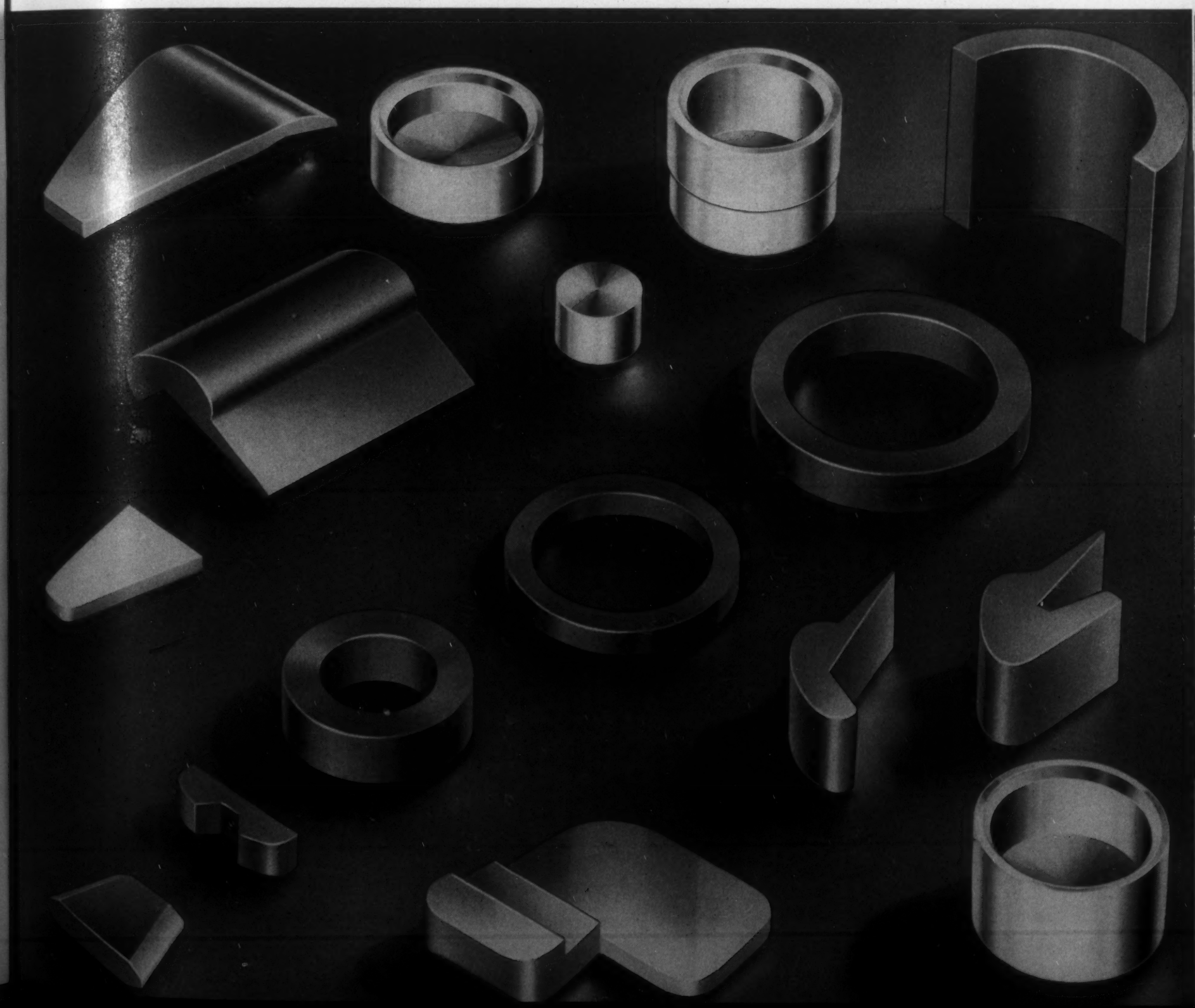
Recent Developments in Cu-W Type Materials

Recent research was directed towards the development of a material having a high electrical conductivity, increased hardness and tensile strength with some ductility. This work was rather successful, as can be seen from the following data:

Hardness	102 to 108 Rockwell B
Tensile strength	125,000 lbs. per sq. in.
Cross breaking strength	210,000 lbs. per sq. in.

Special technique is required in preparation of the material to secure such values, but it is commercially possible to produce copper-tungsten mixtures having a tensile strength of 175,000 lbs. per sq. in., a Rockwell B hardness of 110 and an electrical conductivity of 30 per cent. Materials with these properties have a specific gravity of 14.5 grams per cubic centimeter. This is a rather rare combination of high specific gravity, high tensile strength and high electrical conductivity and such materials may find considerable industrial applications, particularly in industries connected with aircraft, automotive, electrical and instrument developments.

Fig. 12. A variety of shapes producible from copper-tungsten mixtures.



Microscopical Analysis

The structure of a properly prepared tungsten-copper mixture at 1000X is shown by Fig. 10. Attention is called to the fact that the structure is completely free from porosity and that it has the appearance of an alloy in which a secondary phase has been precipitated. For comparison, Fig. 11 is a photomicrograph at the same magnification of a mixture of the same composition, which was improperly prepared. Note the voids and oxide inclusions. All physical and electrical properties determined in the sample shown in the photomicrograph Fig. 11, were inferior and would fall outside of the range of the values given in the curves presented in this paper.

Typical Applications

A number of typical applications are shown by Figs. 12 to 16 inclusive—where metal compositions with a refractory metal base have found extensive use. To a contact metal, the combination of a high conductivity material with one having a high melting point imparts non-welding properties without seriously affecting its capacity to carry large currents. By selecting the proper percentages and ingredients, it is possible to provide the optimum combination of the following properties for specific applications:

1. Resistance to welding.
2. Resistance to electrical erosion.
3. Low contact resistance.
4. Low specific resistance.
5. Resistance to mechanical wear.

Refractory base mixtures can be attached to backing materials either by brazing or by direct fusion. The method is shown in Fig. 13, and in Fig. 14 an actual application is depicted; in this the moving arm is faced with an arcing tip of special composition, high in refractory content. This arcing tip is not called upon to carry current, but only to withstand the arc, during the opening of the circuit. Special materials were developed for oil circuit breakers and for air circuit breakers.

The more recent development in switch gear apparatus has been towards the use of air circuit breakers employing not only a 2-stage contact arrange-

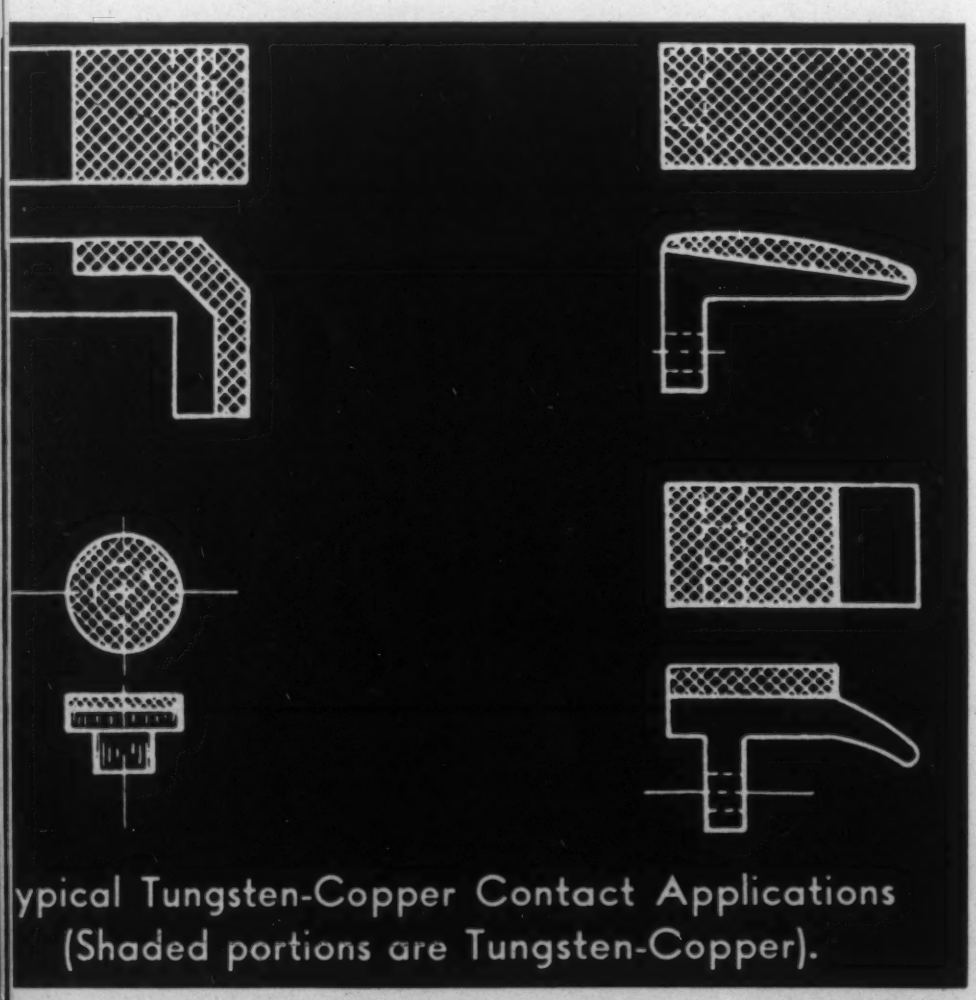
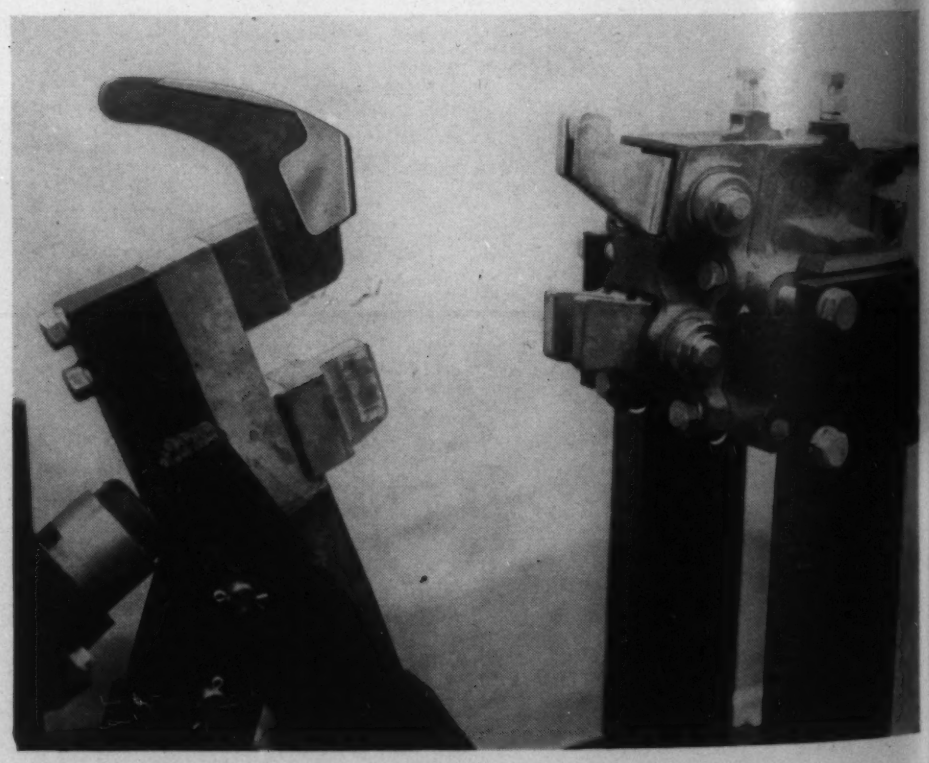


Fig. 13. Typical tungsten-copper contact applications. Shaded portions are tungsten-copper.

Fig. 14. A refractory base mixture attached to backing materials. The moving arm is faced with an arcing tip of special composition, high in refractory content.



ment, but a 3-stage contact arrangement, wherein the first or main contact stage serves only to carry the load, while the second stage consists of auxiliary arcing contacts which serve to protect the main contacts from damage during interruption and also to reduce the time interval during which the arcing contacts proper have to deal with the whole of the current, either during making or breaking. The final arcing contacts comprise the third stage. Special materials had to be developed for each stage.

The construction of two sets of flash welding dies with tungsten-copper facings is shown in Fig. 15. These dies will stand up under high pressure and must have excellent wear resistance. At the same time, the flash does not stick to the tungsten-copper facings. One of the outstanding applications of such dies is in the barrel welding industry. The use of a tungsten-copper facing on flash welding dies will increase the life of the die over that of copper, by approximately 10 to 80 times. In addition, the quality and the uniformity of the welds are greatly improved.

Bushing inserts of tungsten-copper for current carrying bearings are shown in Fig. 16. Solid inserts may be applied for short bearings with small diameters, while for long bearings with large diameters, several longitudinal tungsten-copper inserts are used for each half bearing shell. The wide variety of uses in which copper-tungsten compounds are playing an important role is illustrated by the few applications which have been described.

Conclusions

The physical properties of copper-tungsten mixtures made in accordance with a powder metallurgical process, whose technique has been developed especially for these materials, have been described. Similar information has also been compiled on other combinations, using different refractory bases or different low melting point constituents. A series which has been found of particular interest for electrical contacting materials, is composed of tungsten carbides or molybdenum carbides with silver (U. S. Patent 1,984,203). Systematic information on this system may be presented at a later date, it is hoped.

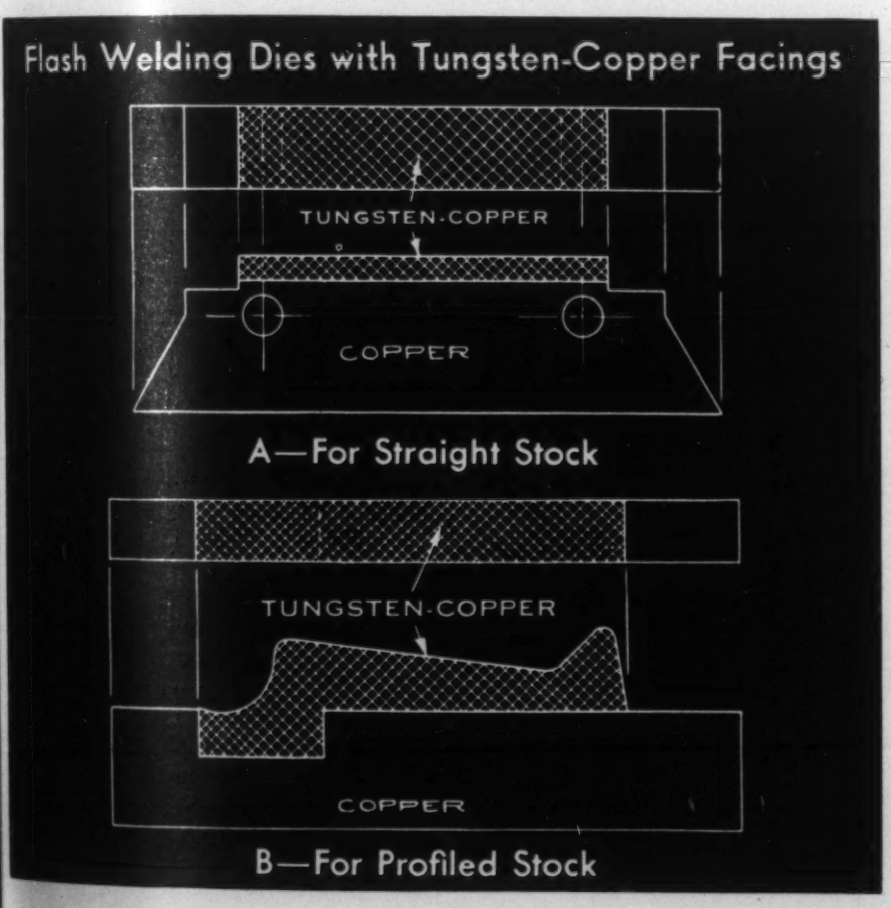


Fig. 15. Flash welding dies with tungsten-copper facings.

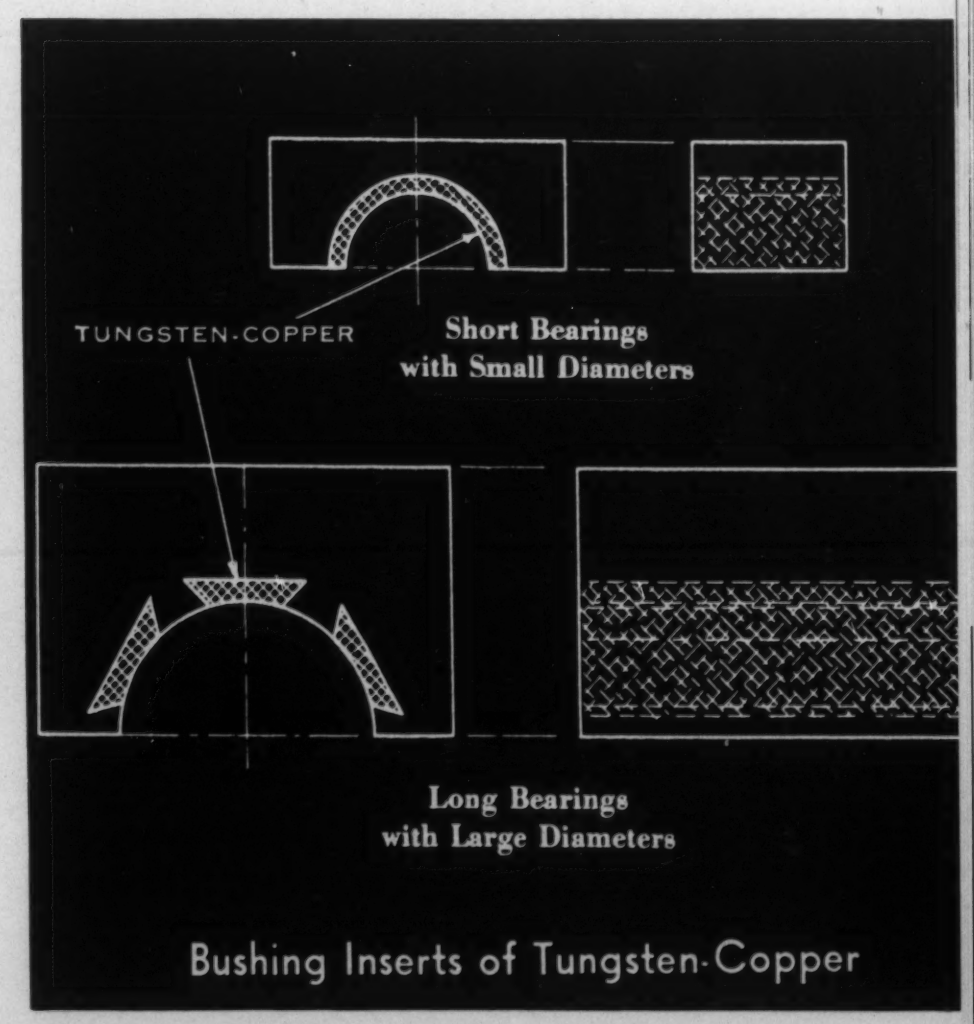


Fig. 16. Bushing inserts of tungsten-copper.

Hydrogen in Steel and Cast Iron—II

AND DEFECTS IN APPLIED COATINGS

by C. A. Zapffe and C. E. Sims

Research Engineer and Supervising Metallurgist, respectively, Battelle Memorial Institute, Columbus, Ohio

From Occlusion in Inclusions

Inclusions and grain boundaries may act as cavities to occlude molecules of hydrogen, or a reaction may occur with the precipitating nascent hydrogen to form a hydrogen compound with the material of the inclusion. Although it has been shown that at ordinary temperatures such reactions are not too likely, it is true that at higher temperatures they do occur. When compounds form, they constitute a separate "fraction" of the hydrogen content and respond to temperature changes in characteristic manners that are important to consider.

For example, a plate as shown in the previous Fig. 5 was prepared with iron oxide (red rouge) in one hole, graphite in the center hole and the third hole was left empty. The plate was sealed and prepared for enameling in the customary manner except that a light pickling treatment was used. Several refirings of the ground coat succeeded in removing the hydrogen from the unfilled cavity, and a cover coat was then applied to show the distribution of the remaining hydrogen (See Fig. 6).

It is seen that the wall directly overlying the unfilled cavity has "boiled down" and shows no trace of hydrogen, in contrast to the previous specimen. To the sides of the hole may be seen small blisters from hydrogen that diffused laterally from the cavity during re-solution. The central hole, containing graphite, has nearly boiled down, but a few blisters are present to indicate that the carbon has effected an almost negligible, though definite, retardation of the hydrogen release. This result conforms well with the fact that hydrocarbons are quite completely decomposed at 870 deg. C. (1590° F.). Lateral diffusion from this central hole is again traced by blisters.

The third hole, containing iron oxide, shows sharp delineation with blisters and a minimum of lateral diffusion. If the hydrogen had not reacted with the oxide at the time of the initial precipitation, it certainly had during heating. As a result, water has apparently formed, and the dissociation of steam in contact with iron is either slower than is the dissociation of molecular hydrogen, or the formation of scale inside the hole has hindered the process of re-solution. In any event, the hydrogen has been largely prevented from effusing during firing, and the fact is significant both to enamelers and to metallurgists. The blistering over this third hole might have been avoided if the piece had been fired at a lower temperature or if an enamel had been chosen that was more permeable to hydrogen.

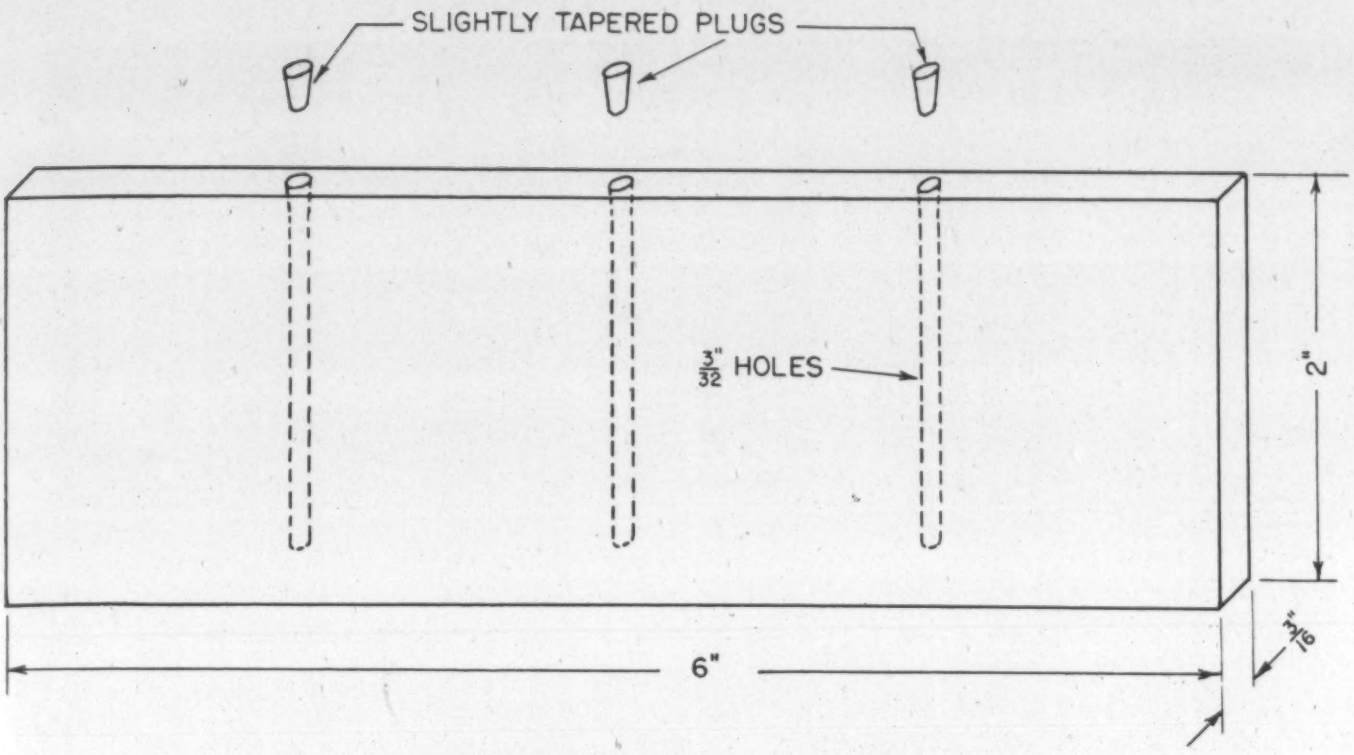
The latter case was indicated by another experiment. Tenth-gram samples of the following types of inclusions:

1. Tephroite: $(MnO)_2SiO_2$
2. Fayalite: $(FeO)_2SiO_2$
3. Open Hearth Slag
4. MnO_2:FeS = 1:1

were placed in specimens of 2-in. round bar stock of plain carbon steel, as shown by sketch in Fig. 7. The cavities were sealed by welding, and the four respective specimens were heated, forged and rolled to about 0.10-in. thickness. Accorded the same treatment, and fired at 870 deg. C. (1600° F.) with the same ground coat as the specimen in the previous Fig. 5, the specimens showed no surface marking whatever that indicated whereunder the inclusions lay. To prove that the inclusions were present, and in gas-tight cavities, the four plates, which had been trimmed considerably, were pickled until blisters arose to reveal the location of the inclusions (see Fig. 7). The non-appearance of enameling defects in these tests may be attributed to a combination of minimized hydrogen effusion from the oxide-containing inclusions and good permeability of the enamel.

From Molecularly Dispersed Impurities, Particularly Carbon

The impurities in steel differentiate steel from the element iron, and the behavior of hydrogen in steel may depart radically from its behavior in iron. Failure to recognize this difference has caused consid-



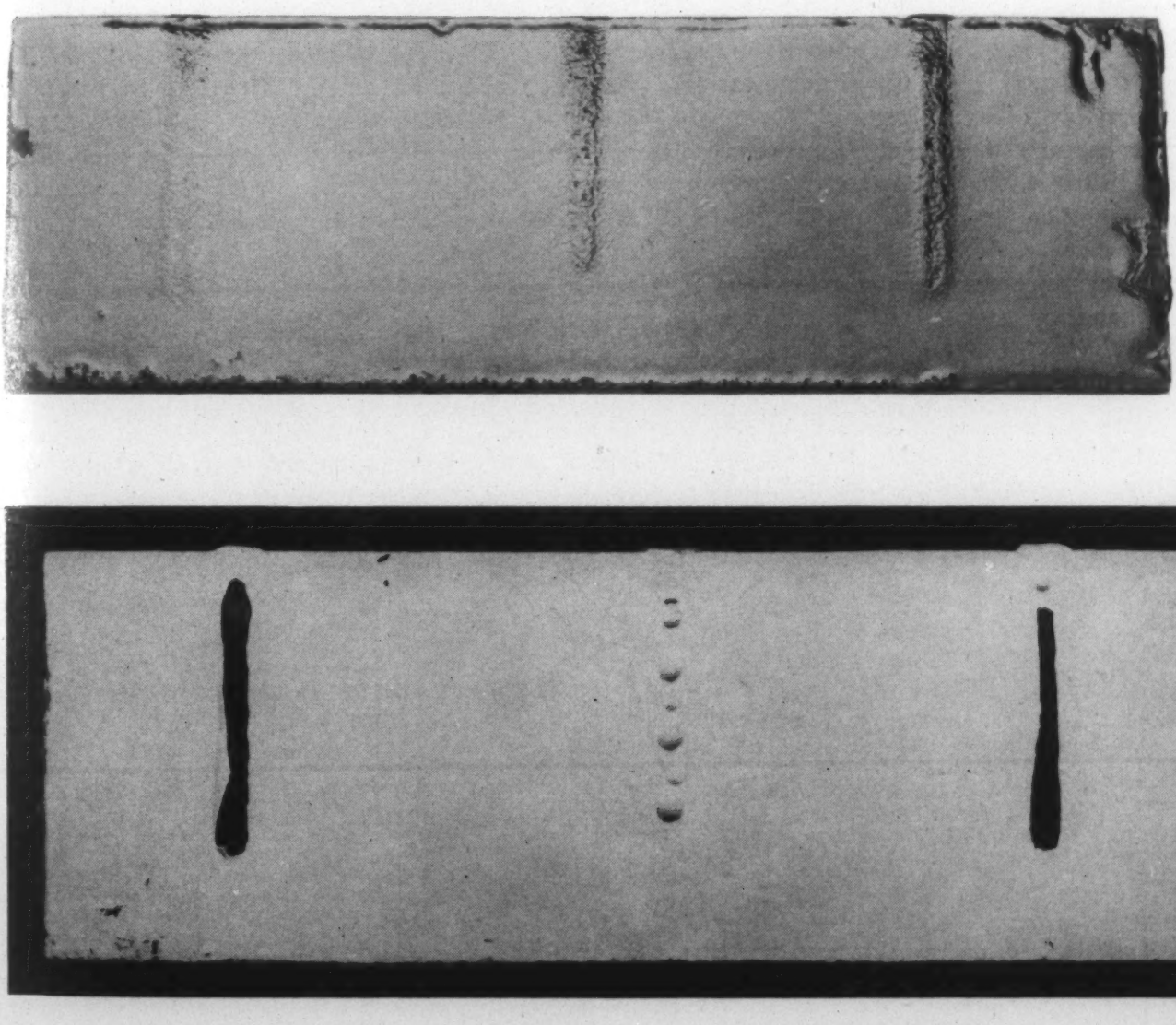


Fig. 5. Steel plate with artificial cavities prepared as shown above. (Center) Fired with ground coat at 870 deg. C. (1600° F.). (Below) Subsequently fired with cover coat at 810 deg. C. (1490° F.).

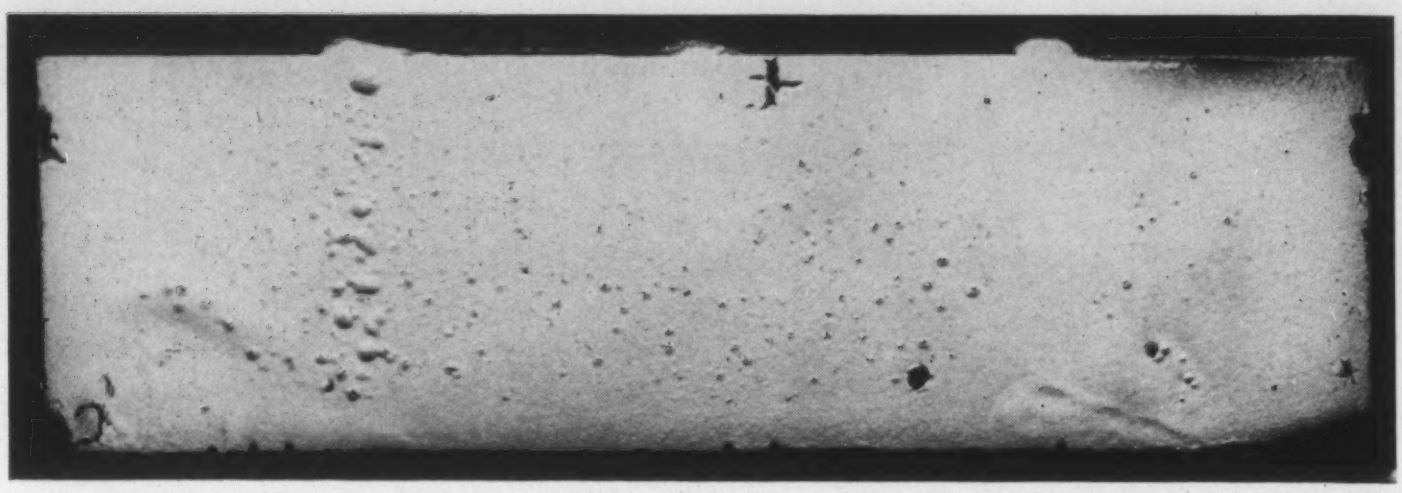


Fig. 6. Steel plate with three artificial cavities containing iron oxide, graphite and air, respectively. Fired with ground and cover coats at temperatures of 870 deg. C. (1600° F.) and 810 deg. C. (1490° F.), respectively. Left end: Red iron oxide. Center: Graphite. Right end: Empty.

erable error and confusion to enter the literature, particularly in regard to hydrogen analyses and to treatments proposed for eliminating this gas from steel.

The most common impurity, and one affecting dissolved hydrogen most strongly, is the element carbon. Boyles[8-10] has shown that hydrogen acts strongly to retain cementite in cast iron, and the present research[4] showed that cast iron containing hydrogen chilled to a much greater depth than iron that did not contain hydrogen. The low oxygen pressure of cast iron is favorable to hydrogen absorption, and Schwartz[11] has found by analysis that white iron contains as much hydrogen as is found in steels showing flakes and shatter cracks. Decarburization by hydrogen is well known, and the efficacy of C-H bond relations in general was discussed in the previous paper.[1] Some additional information follows.

As the carbon content of cast steel increases, the hydrogen that remains in the casting increases. In melts made under one atmosphere of hydrogen, 0.6 per cent carbon is sufficient to cause retention in the casting of as much hydrogen as dissolves in pure iron at the melting point.[12] Low carbon steel loses much of its hydrogen during cooling. Fig. 8 shows that carbon considerably impedes the diffusion of hydrogen through steel, and the effect of spheroidizing on the rate of diffusion is particularly interesting.[13]

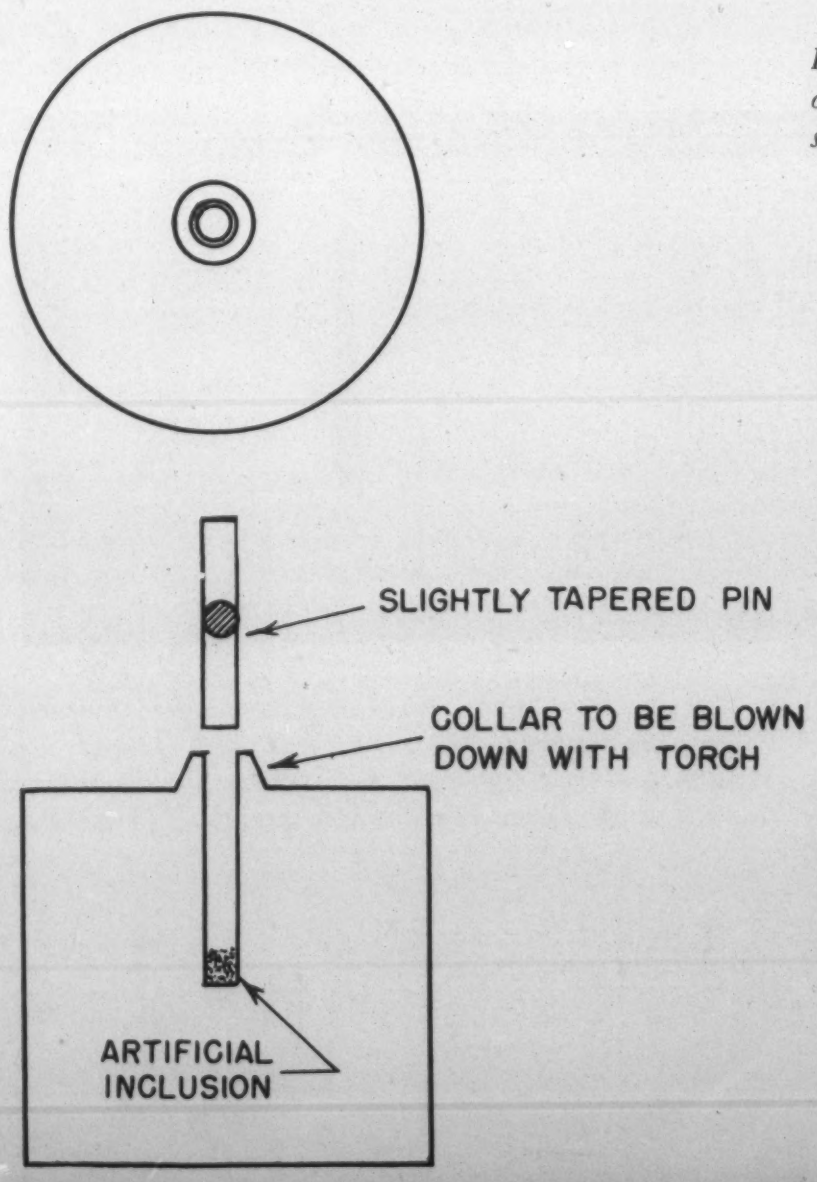


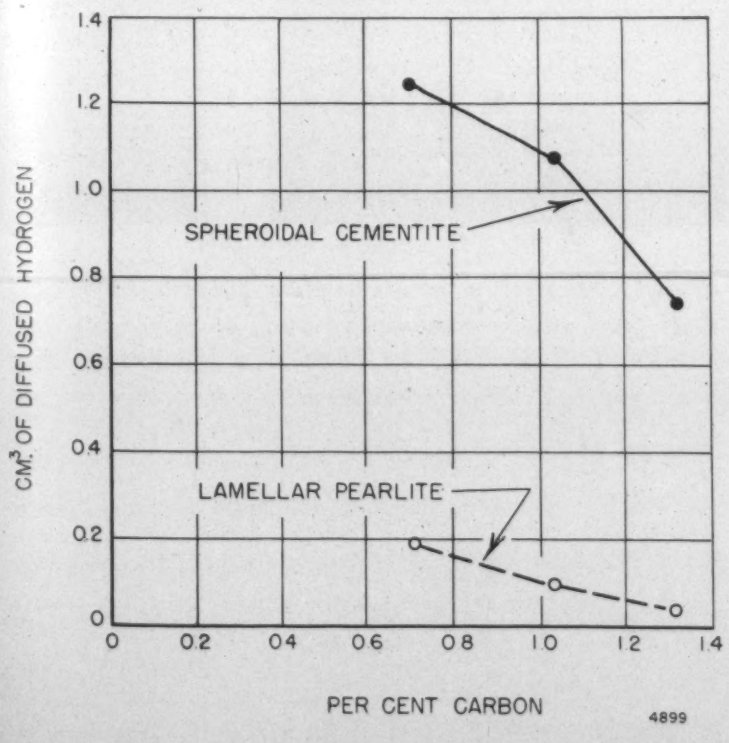
Fig. 7 Artificial inclusions in steel. (Left) Method of introduction. (Right) One of the four de-enameled sheets, showing hydrogen blister at seat of inclusion.

The action of iron carbide during enamel firing is liable to misinterpretation because hydrogen is so closely associated with the carbon. In the present research it was shown that the boiling action in the enamel during firing is principally due to hydrogen that is associated with the carbon, and not to the previously suspected carbon-oxygen reaction. Fig. 9 shows how much more severe is the hydrogen effusion from high-carbon areas than from low.

A 3/16-in. plain carbon steel plate was carburized to a depth of 0.03-in. The case was then ground away except from the rim and the two rectangular areas as shown. The standard pickling treatment afforded saturation of the specimen with hydrogen. During firing there was a severe boiling action over high-carbon areas only, and continued effusion caused the chips as shown. As each blister burst during firing, there was a tiny bright spark that was most likely due to combustion of methane, for either CO or H_2 burns with a blue flame. Micrographs showing the contrasting carbon contents of ridge and plate are presented in Fig. 10. It may be observed that the bubbles in the enamel are larger over the high-carbon area.

The release of hydrogen at elevated temperatures by carbon in steel and iron was shown in another manner by the following experiment. The three holes in a mild steel plate, such as shown in the previous Fig. 5, were carefully cleaned, dried and burned free of hydrogen-containing impurities. In the two outer holes a thin film of machine oil was spread with a pipe cleaner. The holes were sealed as before, but the specimen was cleaned by sandblasting instead of pickling so that a minimum of hydrogen would be absorbed. During firing, the oil decomposed to yield carbon and hydrogen, and the hydrogen diffused through the thin wall over the two end holes to cause blistering in the enamel. There were no blisters over the central hole. It had been observed before by the enameling industry that paint marks on one side of an enameled sheet would cause blistering on the opposite side.

Fig. 8. Effect of content and condition of carbon on the diffusion of hydrogen through 9 sq. in. of 0.05-in. mild steel sheet at 40 deg. C. (104° F.) from 20 per cent (by volume) sulphuric acid. (Bardenheuer and Thanheiser.)

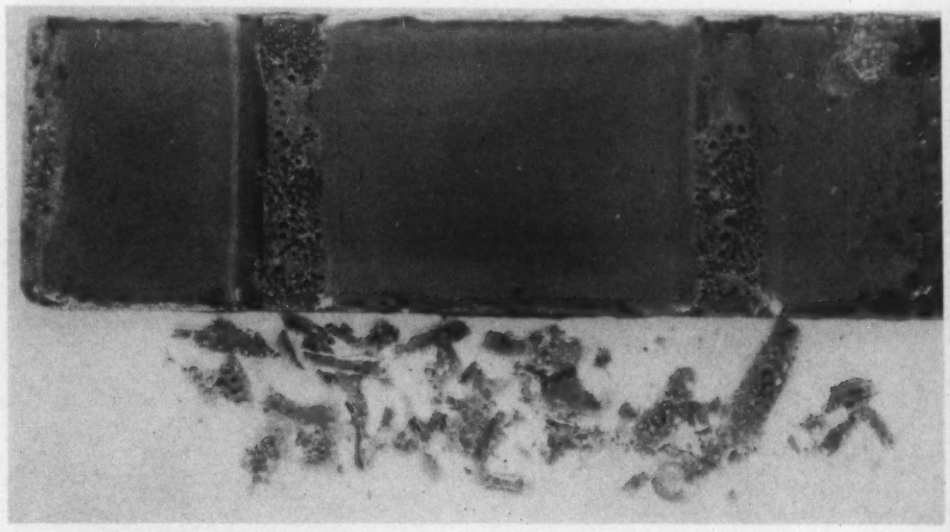


The Effect of Rolling Direction on Hydrogen Diffusion

The banded structure that is so often present in rolled steel has an interesting effect on hydrogen behavior, for the banding comprises, effectively, alternate lamellae of relatively pure and impure iron. The strong effect of impurities on hydrogen diffusion and retention causes hydrogen in such a matrix to diffuse preferentially through the pure metal and hence to diffuse principally in the directions of the rolling plane. Effusion is therefore more severe along the edges of sheet and plate than on the flat face. In enameling, this effect becomes important in "black edging," which is the process of applying a special coating to the edges of sheet ware. In such coatings the numerous hydrogen-caused defects are accentuated. Similar observations with electroplate will be discussed later.

This preferential diffusion of hydrogen in rolled stock is illustrated in the specimen in Fig. 11. A mild-steel rolled plate 1 by 1½ by 5 in. was fired at 870 deg. C. (1600° F.) with a heavy application of

Fig. 9. Mild steel plate with carburized ridges and edges fired with vitreous enamel at 870 deg. C. (1600° F.) showing blistering and chipping caused by effusion of hydrogen released from high-carbon areas.



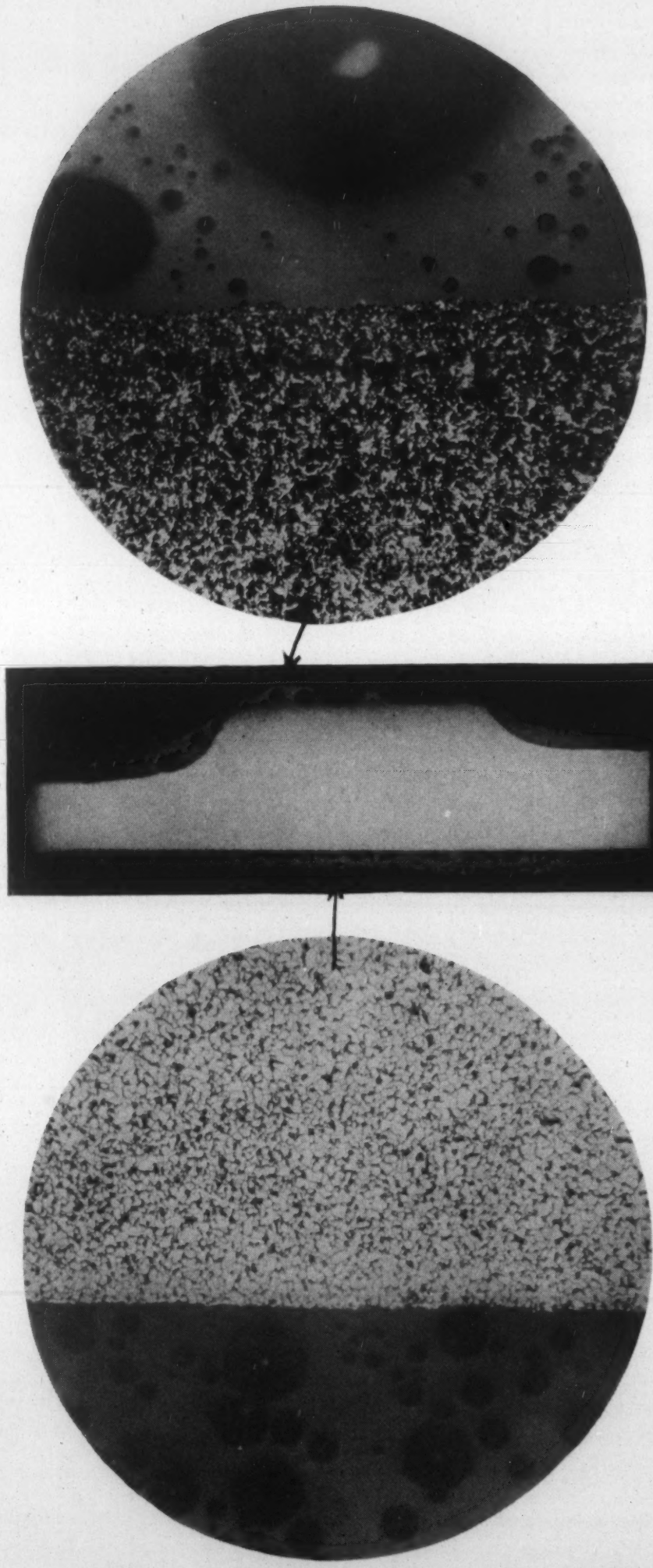


Fig. 10. Micro-sections through carburized ridge of specimen in Fig. 9. Top 150X; center 3X; bottom 150X.

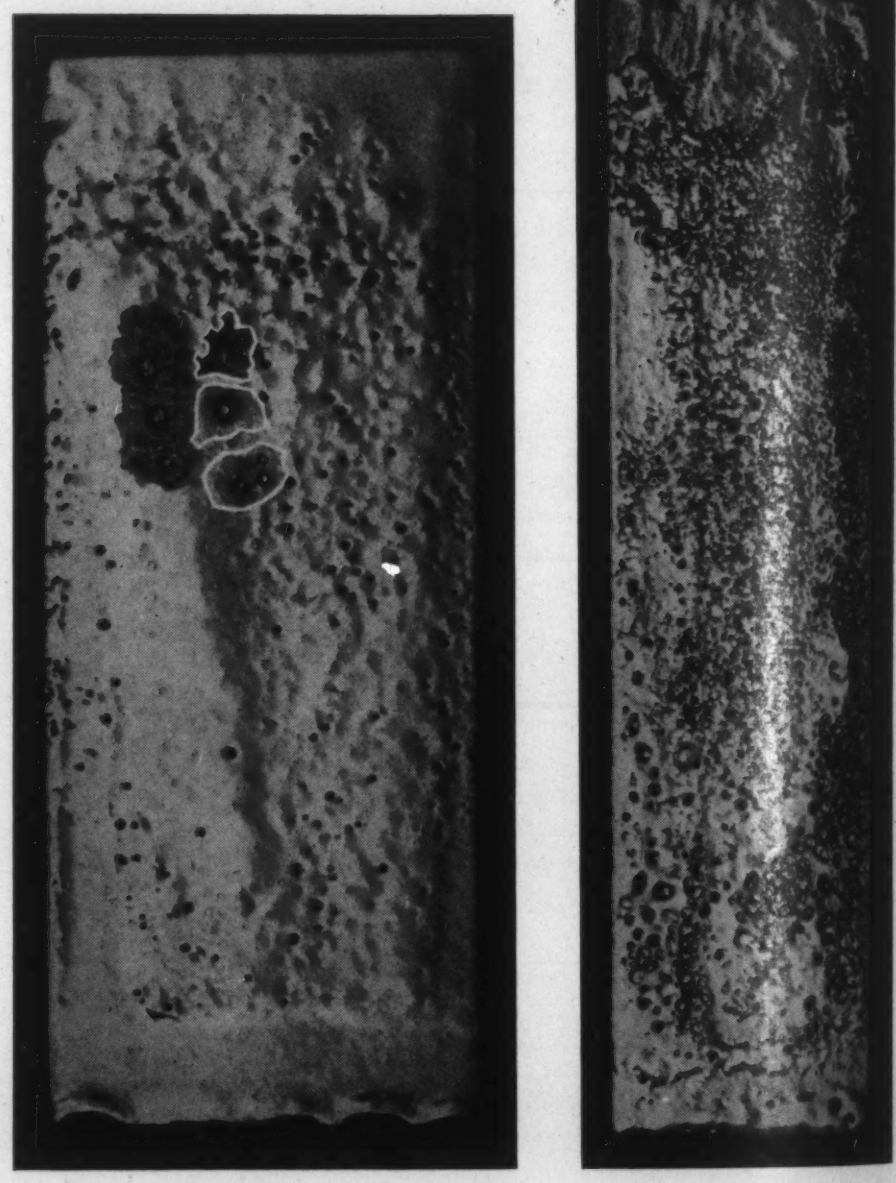


Fig. 11. Rolled mild steel plate pickled with acid and fired with vitreous enamel at 870 deg. C. (1600° F.), showing by blisters in the enamel that hydrogen has diffused preferentially along the rolling plane. Left: Front. Right: Side.

ground coat. The specimen had been cleaned by pickling and, with so thick a plate, ordinary baking periods are entirely insufficient for removing ordinary dissolved hydrogen. During firing, remanent hydrogen effused to cause blistering and boiling, and it is quite evident that the effusion has been much more severe along the side of the plate than on the face.

"Reboiling" in Vitreous Enamel

"Reboiling" in vitreous enameling is an interesting attestation of hydrogen activity. While firing a first coat, boiling may or may not appear, but in subsequent coats a marked boiling action often occurs. In the present research it has been indicated that hydrogen causes the phenomenon. If hydrogen is already in the specimen, "primary boiling" is aggravated, which is about the same phenomenon as reboiling, but occurs in the first coat. During firing the first coat, the moisture in the slip and in the furnace gases decomposes in contact with the iron to form hydrogen and iron oxide, plus some carbon oxides when carbon is present. This hydrogen largely dissolves in the steel, which has an appreciable solubility for this gas at firing temperatures, and thereby "charges" the specimen. If the specimen originally contained less than a certain minimum of hydrogen, the boiling action might therefore first occur during firing the second coat.

The cyclical nature of "reboiling," which has been so puzzling, is then explained as follows: As the specimen heats, the rate of diffusion of hydrogen in steel markedly increases, so that dissolved hydrogen, plus that liberated from other sources during heating, rapidly finds the surface of the specimen. When the enamel fuses, wrinkles are first observed from the rather general effusion; then the wrinkles become bubbles for reasons of surface tension. Many of the first blisters break, but the specimen soon comes to a temperature where the solubility of hydrogen in steel markedly increases, and the bubbles can then be observed to recede and the boiling to subside as the hydrogen re-dissolves in the steel. The great permeability of steel for hydrogen at enamel-firing temperatures is shown by the fact that steel enameled only on one side rarely ever blisters.

The specimen is then uniformly saturated with hydrogen as if it were in equilibrium with an atmosphere of the gas, which it truly is, for the enamel coating protectively affords such an atmosphere. Cooling causes supersaturation and, after the gas disperses to its various lodging places in the steel, the specimen is in much the same condition as it was before firing. Subsequent firings provoke the same cycle of hydrogen activity except that each time a portion of the gas is lost, principally in the heating and cooling interval, so that after 20 or more firings "reboiling" no longer occurs. Also, similar to preventing flakes and shatter cracks, slow heating or slow cooling will prevent reboiling.

(To be continued)

(Editorials—Continued from page 557)

When a metal part is to be provided to do a tough job, such as in resistance to fatigue, wear, corrosion, high temperature service, etc., the so-called metallurgical engineer who rests content with merely trying to find a better metal, and pays no attention to possible changes in design or control of service conditions that would solve the problem more simply, isn't a metallurgical engineer at all, he's just a metallurgist.

The plant that isolates its metallurgical activities from the engineering phases of its work is operating under a handicap.—H. W. G.

From Special Steels to Machine Tools

That well-meant, but poorly thought-out, restrictions upon production and use of some commodities may serve to hamper rather than advance the defense program, is indicated by an example cited by a correspondent whose firm produces articles that are as indispensable in the conduct of war as they are in the conduct of business. This correspondent says:

> We have a situation in connection with the material stringency, which I think deserves editorial comment. High accuracy screws, pinions and shafts, have been produced on automatic screw machines from leaded LX-1112 steel. Because of the superior machineability of this steel, the number of screw machines necessary for producing our very considerable requirements is only about one-half what would be necessary with ordinary screw stock because of the reduced speed and feed which we would have to use. Today, with the steel companies reluctant to devote production capacity to special steels, it is becoming practically impossible to buy LX-1112. A point on which emphasis could well be placed is that by continuing and increasing the availability of super-machining leaded steels, we could help to solve the national bottleneck due to shortage of machine tools.
>
> Life is just one round of determining satisfactory substitutes due to the stringency in the supply of aluminum, zinc, nickel and other tight metals. Plastics are coming in fast as metal substitutes and in many fields the replacements will be permanent. One consoling feature of the present situation is that, in a number of cases, we are finding that forced replacements of such materials as zinc die castings and wrought brass parts are being made with consequent economies at no apparent sacrifice in utility.

This willingness to use substitutes where they will serve is characteristic of industry in general in the emergency, even in firms very hesitant to make any changes in normal times, and it makes a background against which a case where a shortage does create an insufferable hardship stands out in bold relief.

The struggle will still go on between the producer's urge to make the fewest possible number of standardized steels and the consumer's desire for a tailor-made steel when it does a particular job better than the tonnage steels. As we have remarked editorially before, the real trouble is that the making of tailor-made steels is properly a job for a small plant, equipped and managed for maximum flexibility rather than maximum output. In times like these the large-production plant should welcome the opportunity to direct a customer's request for a specialty product to the more flexible plant instead of just telling the customer to go to hell. It is when operations are at a low level that the large-production plant will not only shift the specialty order, but its salesmen try to drum up such orders for itself. The managements of the big plants should realize that by allowing the little specialty plants to do business in slack times, the benefits they bring in times of crowded production would far more than repay that degree of decent consideration.

Perhaps the customers can do something about this in slack times by placing their orders with the little fellow in spite of sales pressure from the big fellows.—H. W. G.

A Couple of Chuckles

A Movie Boner?

Letters from all over the country are being received by the Chase Brass & Copper Co., commenting on a "movie boner" that appeared in the current motion picture "All This and Heaven Too," co-starring Bette Davis and Charles Boyer. This photoplay is laid in the middle of the last century, in 1846, yet in one scene Bette Davis received as a gift an old fashioned brooch enclosed in a modern gift box used by the Chase Brass & Copper Co. to package their line of brass, copper and chromium giftware. A close-up of the box showed the Chase trade mark, adopted in 1929 (half man and half horse, shooting a bow and arrow), some 73 yrs. after the time represented in the movie.

Inasmuch as the gift enclosed in the box received by Bette Davis in the photoplay was not manufactured by Chase, the perplexed officials of the company have not decided whether this is a "break" for their products or not.

Carats in Gold?

To the Editor: In the January, 1941, number of METALS AND ALLOYS on page 88 in an abstract of an article on gold plating it is stated that "the anode is 27-carat fine gold." (The original article states 22-carat gold). Just how many carats are there in $35.00 gold?

W. BLUM
Chemist

National Bureau of Standards
Washington, D. C.

METALLURGICAL ENGINEERING news

Equipment
Finishes
Materials
Methods
Processes
Products

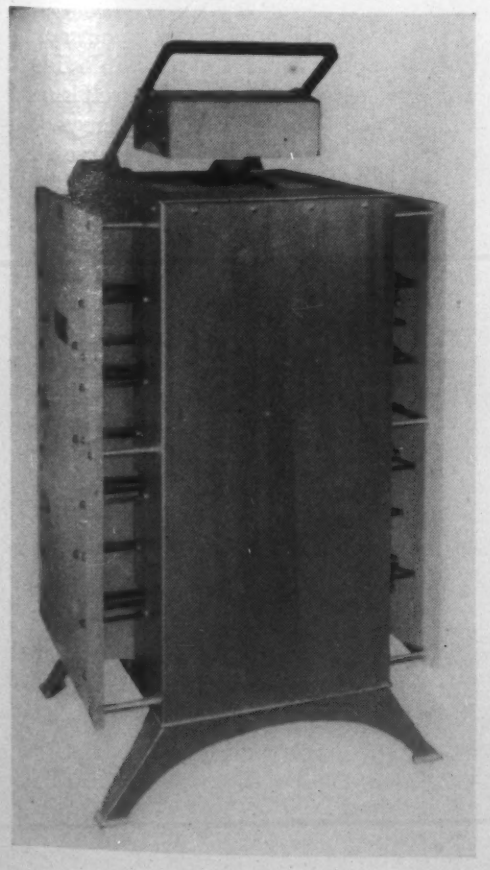
Alloys
Applications
Designs
People
Plants
Societies

Heat Treating — Furnaces, Atmospheres, Etc.

With America re-arming in haste, every possible means available to metallurgical engineers for speeding production and eliminating or avoiding bottlenecks must be explored. One practice whose wider adoption might considerably ease the machine-tool situation and save finishing time is the use of controlled atmospheres for *bright* hardening wherever possible; tools, dies and parts can be previously formed exactly to size and subsequent grinding to remove "bark" can be eliminated if they are hardened in atmospheres that do not decarburize or scale.

High Speed Steel Hardening

A controlled atmosphere pit-type electric furnace for high-temperature hardening of high speed steel has been designed by *Sentry Co.*, Foxboro, Mass. It allows the hardening of long tools in a vertical position and minimizes warpage of the tools while hot. The neutral, non-decarburizing atmosphere is obtained by the use of Sentry Diamond Blocks.



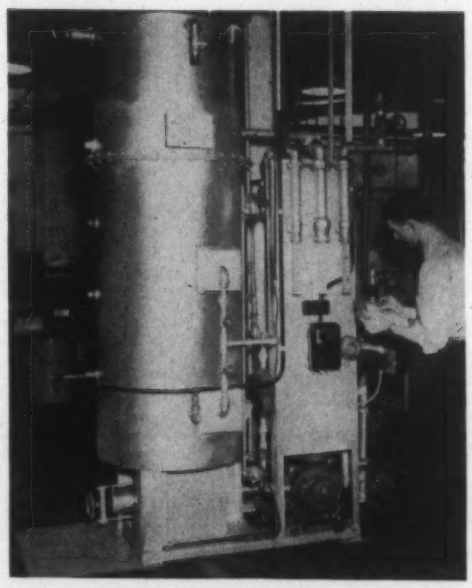
The new furnace, with a maximum rating of 32 kilowatts, will heat from room temperature to 2350 deg. F. in 75 min. The heating elements on either side of the removable silicon carbide muffle, in 4 positions, assure uniform temperatures throughout the chamber. The electrical terminals are air cooled. Muffled dimensions are 4½ in. by 4 in. by 28 in. deep, and the over-all dimensions are 52½ in. high, 28⅞ in. wide, 21½ in. deep.

Atmosphere Producer

Another type of controlled atmosphere, which is reported by the *General Electric Co.*, Schenectady, N. Y., to be giving decarburization free service in several industrial plants, is drycolene.

The GE drycolene producer, available in sizes of 200 and 750 cu. ft. per hr., is a gas-fired reaction chamber with a number of accessories—all mounted as one self-contained unit. In operation the producer burns a suitable hydrocarbon gas with air under controlled conditions, and the products of combustion are passed through a moisture-removal system and then through incandescent charcoal. The final dried and filtered atmosphere contains practically no carbon dioxide or water vapor.

Steel hardened in drycolene has been found to be hard right to the surface. For example, tests on S.A.E. 52100 and S.A.E. 1090 steels heated in drycolene for 2 hrs. at 1500 deg. F., and quenched, showed slight increases of weight and slightly higher converted Rockwell N (superficial) readings than the Rockwell C readings, indicating no decarburization. Depending on the type of hydrocarbon gas used, the cost of drycolene will range from 16c per 1,000 cu. ft. to 57c per 1,000 cu. ft.



Oil-Gas Burner

A new development in furnace burner systems is the O-G burner of *Oil-Gas Combustion Co., Inc.*, 17 Whitney Ave., New Haven, Conn. The burner is a portable self-contained unit that converts fuel-oil into a gas.

By creating a gaseous fuel from the oil, a homogenous mixture of fuel and air is obtained, and since no excess air is necessary to complete combustion, the atmosphere is readily controlled to produce a reducing, oxidizing or neutral gas as required. The burner consists of a two-stage blower, motor, oil valve, mercury-switches, air and oil connections, and a heat resistant alloy combustion chamber in which complete gasification of the oil is accomplished.

The burner weighs 23 lbs. and has a heat output of 25,000-135,000 b.t.u. per hr. The oil-gas is generated from range oil or No. 1 fuel oil, and the burner can be operated continuously or intermittently. It is said to be applicable for ordinary impingement and convection heating for hardening, annealing, forging, etc. and for infra-red radiant burner heating for drying surface finishes.

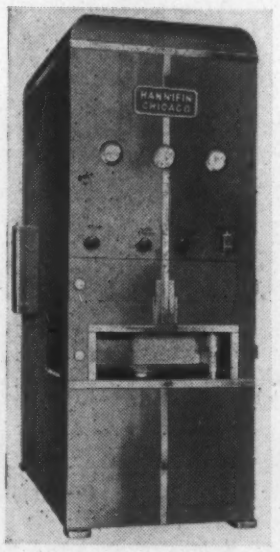
Butterfly Valves

An improved butterfly valve in which internal parts are machined to assist operation and to obtain a tight fit between housing and vane has been developed by *R-S Products Corp.*, 4530 Germantown Ave., Philadelphia. The valve is applicable for air or gas control, and is available for hand, hydraulic or motor operation. The line includes sizes from 2-48 in., covering working pressures up to 15 lbs.

A design feature is a pair of adjustable stops provided to stop the vane in either of two set positions between open and closed. This permits constant duplication of any set maximum or minimum opening in addition to fully-opened and tightly-closed positions. All valves have a graduated dial and pointer for the exterior determination of the vane.

Quenching Machine

A new centrifugal quenching machine produced by *Hannifin Mfg. Co.*, 621 So. Kolmar St., Chicago, provides accurate and



controlled quenching of all types of circular parts on a fully automatic basis. In operation the circular parts (gears, for example) are placed in a holding fixture and then put through the automatic quenching cycle.

In this cycle all variables—temperature and volume of quenching fluid, immersion time and turbulence of quenching medium—are adjustable and pre-set. The quenching fluid is introduced at one corner of the tank, and a circular motion is accomplished and the temperature kept constant by a continuous influx of fresh quenching medium.

● Reduction of destructive shock and of noise in a bronze punch-press drive-pinion used for heavy stamping operations was achieved in one case on record through the use of a "Torflex" bearing—a steel sleeve keyed directly to the drive shaft and separated by a rubber wall from an outer steel tube that makes a press fit with the pinion. The bronze pinion so rigged outlasted fibre gears by over 6 times, yet with a quietness of operation impossible with steel gears, according to *Harris Products Co.*, 5408 Commonwealth Ave., Detroit.

Oxygen-Recorder for Gas Analysis

A completely automatic oxygen recorder, which provides continuous indication and graphic record of the amount of oxygen in any gas, is announced by *Cambridge Instrument Co.*, Grand Central Terminal, New York. No chemicals are used with this instrument, which operates from the electric supply line.

The instrument is described as particularly valuable in the control of inert atmospheres—in billet heating, annealing, bright hardening, etc. The standard range is 0-5% oxygen on a 10-in. scale, but the instrument can be scaled in ranges of 0-2% oxygen full-scale and 0-100% oxygen full scale.

Determinations of oxygen are not affected by variation in the constituents of the sample gas because a differential measurement is performed. Various analyzing cells may be combined so that the instrument will provide a complete gas analysis on one chart.

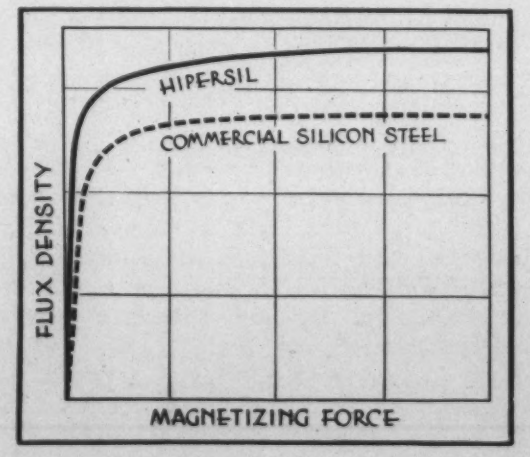
The principle of operation of the new instrument comprises the conversion of all the oxygen in part of the sample to carbon dioxide by passing a portion over a hot carbon rod, followed by a continuous measurement of the difference in thermal conductivity between the original sample and the "converted" sample.

New Transformer-Core Steel

A new type of transformer-core steel, with ⅓ greater flux-carrying capacity than the best conventional silicon steel, has been developed jointly by *American Rolling Mills Co.*, and *Westinghouse Electric & Mfg. Co.*, and is now used exclusively by Westinghouse. The new steel, known as Hipersil, requires no more magnetizing force in carrying this increased flux, and its loss will be no greater than ordinary transformer steel. Furthermore, its magnetostriction is reduced so that the increased flux causes no increase in hum.

In its first application the new steel is said to have reduced the size and weight of distribution transformers as much as 25%, and has facilitated the reduction of copper losses by 10% with thereby increased short-time overload capacity. The chart shows schematically the difference in magnetic behavior between commercial silicon steel and Hipersil.

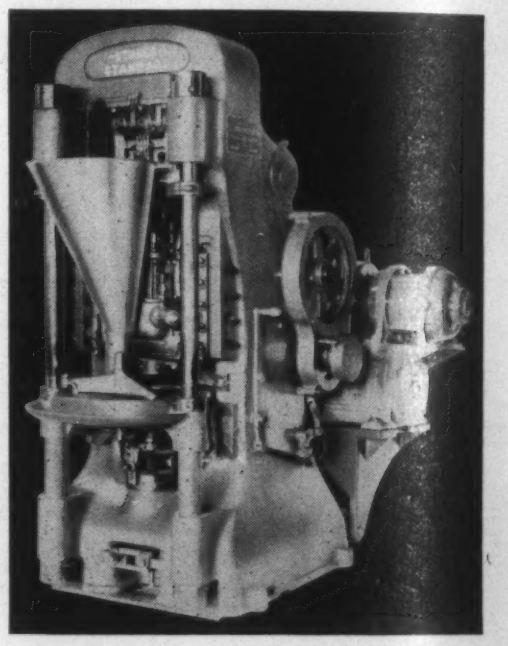
The properties of the new steel depend more on a special type of crystal orientation than on modification in analysis. The steel is produced by methods that result in orientation in the direction of rolling (ordinary silicon steel has completely random orientation) and the new material is easily magnetized in this direction. Although its flux-carrying capacity in this direction is ⅓ greater than ordinary hot-rolled silicon steel, it would be much less effective than the older material if used at right angles to the crystal orientation.



● A new and larger (14 in.) carbide tool grinder of the double-end type designed so that 2 operators can grind tools simultaneously, is now available from *Carboloy Co., Inc.*, Detroit.

High Pressure Powder Metallurgy Presses

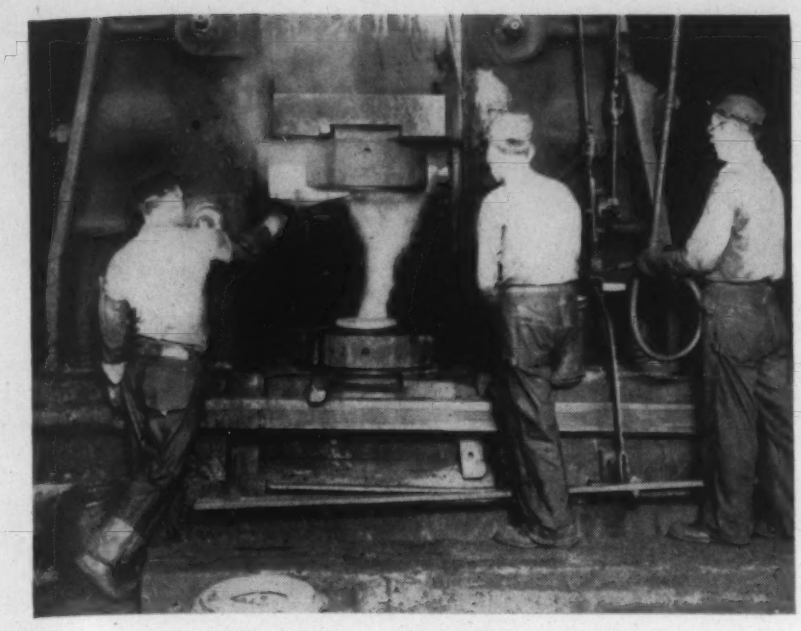
To meet requirements of maximum hardness and density in iron gears, bushings, valve inserts and other parts pressed from powdered metals, *F. J. Stokes Machine Co.*, Tabor Rd. E. of Adams Ave., Philadelphia, is offering an automatic self-contained cam-



operated toggle type press similar in design to a smaller press now in wide use. The new press—No. 280—is well suited to the production of thin-section, large-diameter parts as well as other powder metallurgy products requiring pressures up to 100 tons during compressing.

The new press opens and closes rapidly in the clear but the toggle action automatically slows down the movement after the punch and die are finally closed, giving a high output—up to 50 strokes per min.—yet without sacrifice of smooth pressure application and maximum density. The presses are of rugged construction, with Meehanite frame reinforced by heavy tie rods. It is fully automatic, has a 2-in. die-fill, and produces such parts as iron rings with a maximum of 4-in. diameter.

● A new rotary type vacuum pump operating without gears, springs or valves and said to be unusually efficient, vibrationless and quiet, is announced by *Gast Mfg. Corp.*, Benton Harbor, Mich. It is very compact and light-weight, and has an air capacity of ½ cu. ft. per min.



Forging dies are swabbed occasionally with oil containing colloidal graphite to eliminate sticking in deep forging work at Kropp Forge Co., Chicago. According to Acheson Colloids Co., better finish and reduced die wear thus result.

This drop hammer is shaping a tool fitting at a Timken Roller Bearing Co. plant. Although of mammoth proportions, a hammer like this can be so closely controlled by an expert as to break a watch crystal without damaging the "works."

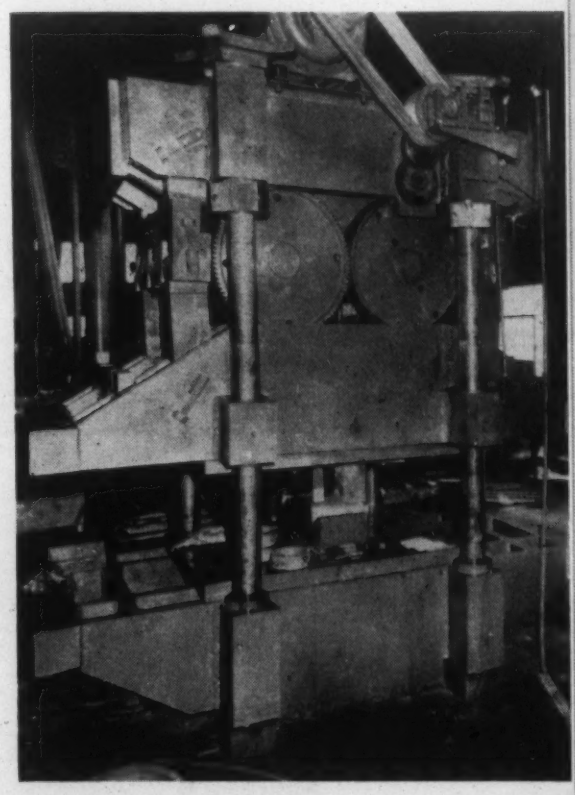
new things

and old in

Forging

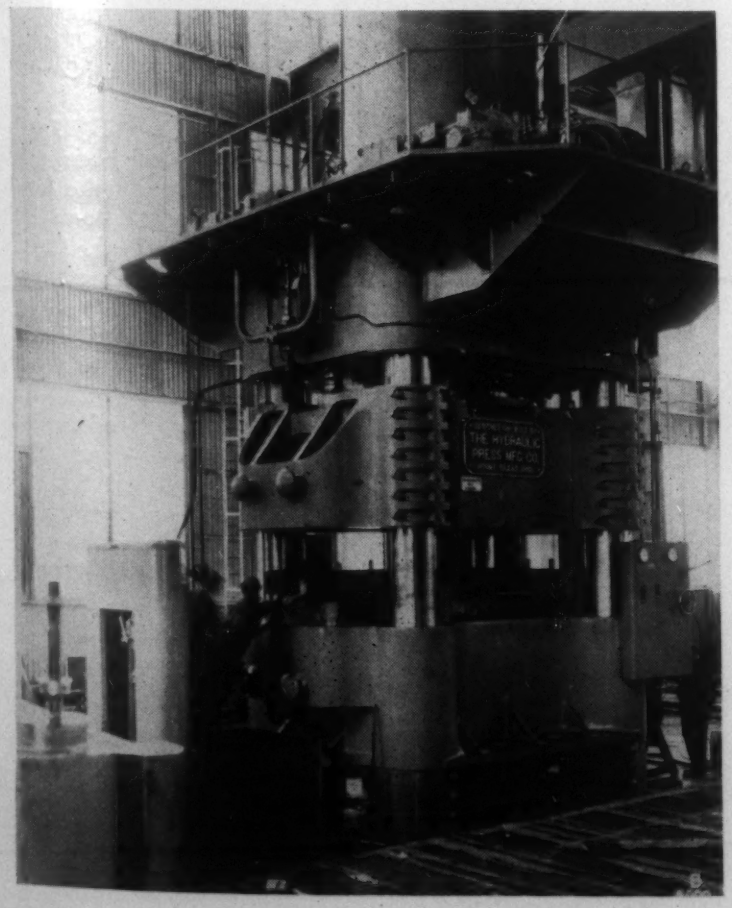
and

Forming



Here is a 700-ton metal-forming press fabricated by arc welding in only 35 working days, according to Lincoln Electric Co.

In the Guerin process for blanking and forming aircraft parts (described in our Oct. 1940 issue, page 436) a heavy rubber punch pad is used. This picture shows a 14 ft. x 4 ft. rubber press pad, weighing 2 tons, being installed in a giant 5000-ton press destined for a British aircraft plant, according to B. F. Goodrich Co.



A heavy forging operation at the Bethlehem, Pa., plant of Bethlehem Steel Co.

Blackening Zinc and Its Alloys

Zinc and its alloys can be conveniently blackened by a new immersion process developed by the *Enthone Co.*, 442 Elm St., New Haven, Conn. Known as "Ebonol Z," the new process consists in immersing the zinc or zinc alloy parts in a 1 lb. per gal. solution of Ebonol Z salts at 150 to 212 deg. F.

An adherent jet black finish is formed in 1 to 5 min. It is stated that 1 lb. of salts will blacken over 150 sq. ft. of zinc surface and the bath requires little control. The solution is also useful for producing a black coating on stainless steel, "nickel silver," nickel and precious metals by making a couple with these metals and a piece of zinc.

Among the more interesting potentialities of the process are its use for finishing name plates and etchings where recesses must be blackened and for blackening armament products to reduce glare. Zinc plated on hot galvanized surfaces as well as solid zinc and its alloys can be treated.

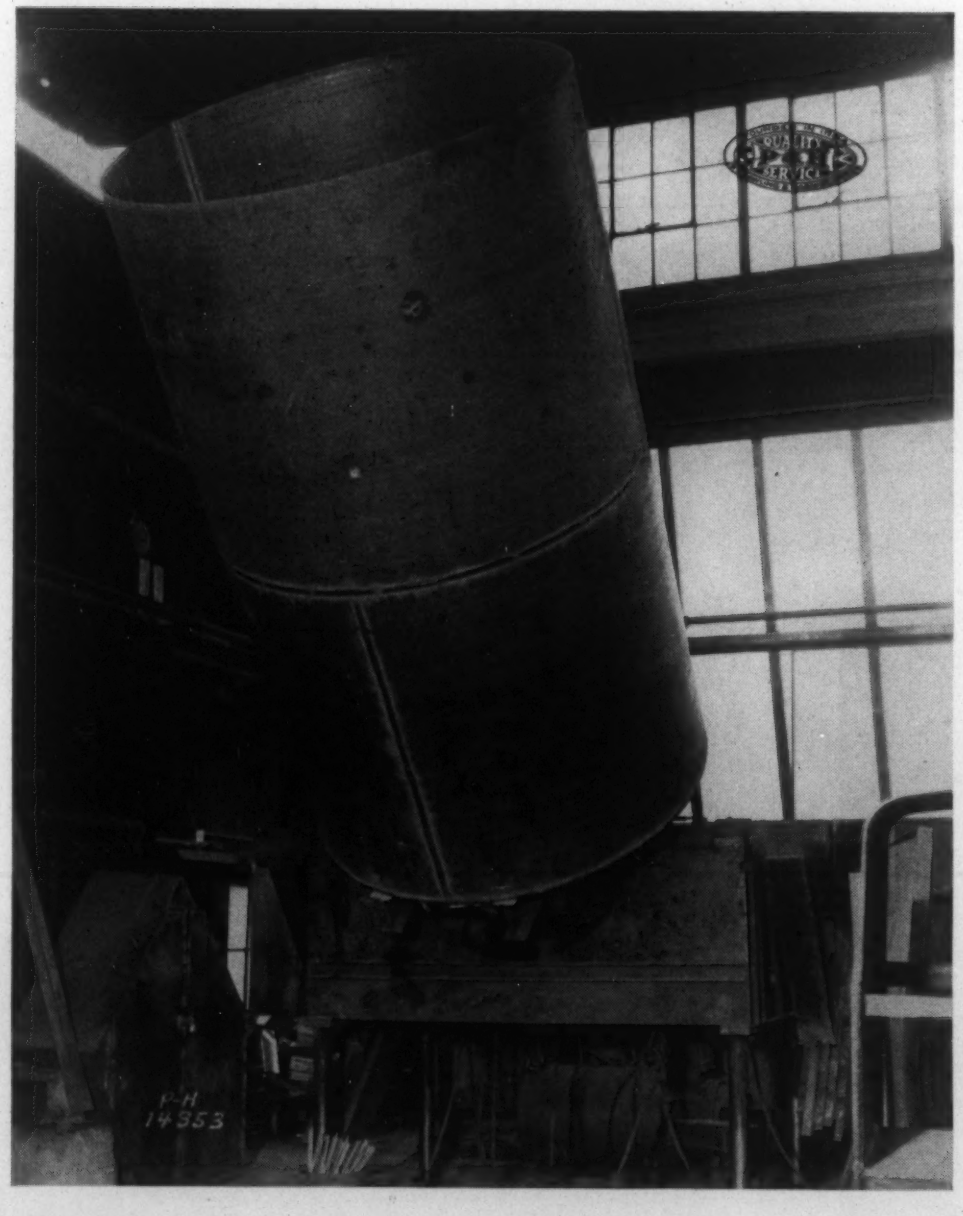
New Process Babbitt-Lined Bearing

The Evans "Fusion-Bonded" steel-backed, babbitt-lined bearing, recently announced by *Curtis Development & Mfg. Co.*, 3266 No. 33rd St., Milwaukee, Wisc., is said to be made by a special process that gives it unique performance qualities.

Specifically, an unusually flexure- and cracking-resistant bond, uniform bearing structure, and higher load-carrying capacity at elevated temperatures are claimed, together with good conformability, embedability and non-scoring qualities. Brinell hardness, 22.8 at 72 deg. F. is as high as 19.3 at 207 deg. F. and 16.6 at 300 deg. F., it is said.

Present production sizes are limited to 1.125-4.00 in. I.D.

Arc-Welded Tank for Quenching Gears



Fast production, weight-saving and pressure-tightness have been achieved in the fabrication of this gear-quenching-tank by arc welding, reports *Harnischfeger Corp.*, 4460 W. National Ave., Milwaukee, Wis., at whose plant the tank was manufactured. Welding time was cut about in half by the use of an automatic positioner.

The tank, 10 ft. deep and 6 ft. in diameter, was made from two 5-ft. sections of ½-in. mild steel plate welded together. The tank, after construction, weighed 2600 lbs.—33% less than the weight of a similar riveted tank.

● A standard type of carbide-tipped boring bit that will give efficient service on most steel boring operations, while requiring minimum grinding alterations for special jobs, has been placed on the market by *McKenna Metals Co.*, 158 Lloyd Ave., Latrobe, Pa. The "Kennametal" tips on these tools are said to permit high cutting speeds on steels up to 550 Brinell hardness.

New A.C. Arc Welder

"Simplified welding" is the claim made by *Ideal Commutator Dresser Co.*, 1928 Park Ave., Sycamore, Ill., for its new a.c. arc welder. Fifteen different welding heats between 20 and 175 amps. are available, and penetration may be up to ¼ in. or more, if desired.

The design includes a reactance winding on a separate core in addition to the transformer. This winding stabilizes the system and makes easy the striking and holding of an arc, and also causes the voltage to vary proportionately, so that the arc is always smooth.

The standard welder is for 230 volt, 60-cycle operation; full-load current is 52 amps. Welding rod should be between 1/16 in. and 5/32 in. diam. The unit weighs only 190 lbs.

● A new ultra-fast method of working lacquered or enameled metals without engraving has been developed by *Automark Corp.*, Elizabeth, N. J. The process consists of a steel die application to the coated metal under electrically controlled conditions.

Personals

General Alloys Co., Boston, announces that *Roger Sutton*, former Chrysler metallurgist, is the company's new director of engineering and metallurgy, and *L. M. Lindsey* its new engineering sales manager. . . . *Harry E. Orr*, hitherto chief metallurgist of Burnside Steel Foundry Co., is now sales engineer for Vanadium Corp. of America at Chicago.

R. S. Marthens, manager of Westinghouse's gearing division, has been named staff assistant to the manager of the Canton Ordnance Division at a plant now being built. . . . *Gustav E. Guellich*, formerly of George Scherr Co., is now metallurgist of Spencer Lens Co., Buffalo.

H. A. Pray has been appointed head of the new division of electrochemical research at Battelle Memorial Institute, Columbus, O. . . . *Raymond R. Ridgway* of the Norton Co., Chippawa, Ontario, was elected president of the Electrochemical Society at its recent meeting.

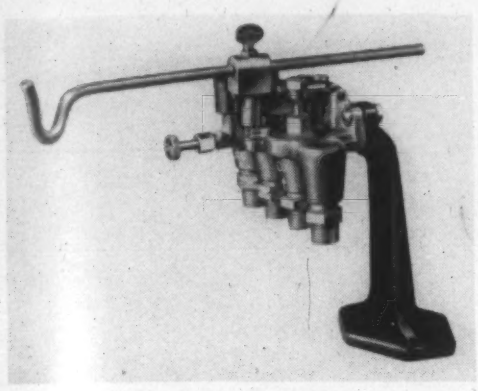
The American Foundrymen's Association will award the following medals at its annual convention: The Joseph S. Seaman medal to *Charles E. Hoyt*, the Association's executive vice president and exposition manager . . the J. H. Whiting medal to *Donald J. Reese*, International Nickel Co. engineer . . the W. H. McFadden medal to *Max Kuniansky*, general manager of Lynchburg Foundry Co. . . and the John A. Penton medal to *Fred L. Wolf*, technical director, Ohio Brass Co.

Welding-Gas Economizers

For jobs where welding operations are intermittent—where welding torches are on-and-off because of work set-ups—a new model (4360) Rego economizer designed to save up to 30% in gas and operator time is now available, according to its manufacturer, *National Cylinder Gas Co.*, 207 W. Wacker Drive, Chicago.

This new model is intended for very light-weight torches and for torches that operate at unbalanced gas pressures. The shut-off action is fast, positive and leak-proof, owing to the diaphragm-type shut-off valves.

The shut-off valves on the lever arm assembly are equipped with adjusting



screws which, when set for the torch pressures being used, assure correct seating. An extendable lever arm provides the adjustability required for positive shut-off with light-weight torches.

The model operates with pressure unbalance as extreme as 3 oz. acetylene pressure to 50 lbs. oxygen; with torches at equal or balanced pressure up to 25 lbs.; and by adding a weight to the lever arm, with balanced pressure up to 50 lbs.

Hot-Tinning Flux

A new hot-tinning development is a special tin flux known as "Fas-Tin-Flux," made by the *Hanson-Van Winkle-Munning Co.*, Matawan, N. J. The product is a liquid of the zinc-chloride type, and is used for hot tinning and soldering and in the manufacture of terne plate.

The flux contains special addition agents to assure fast action, and is so made that it will be free from uncombined hydrochloric acid. The flux should be used at full strength, but it may be diluted if desired. For best results, the flux fusion made from Fas-Tin-Flux should be kept on the tin pot and the entering work passed through.

This flux may be poured on molten tin without danger of explosion, it is said, and will form a foamy flux blanket, which is constantly supplied with water by a drip. It is claimed that 100 lbs. of this flux will accomplish as much as approximately 135 lbs. of 50 deg. Baume zinc-chloride fluxes.

● Because the scope of its service has come to include the broad field of basic refractories in general as distinct from just dolomite refractories, Basic Dolomite, Inc., Cleveland, has changed its name to *Basic Refractories, Incorporated.*

Meetings and Expositions

NATIONAL ELECTRIC MANUFACTURERS' ASSOCIATION. Hot Springs, Va. May 12, 1941.

AMERICAN FOUNDRYMEN'S ASSOCIATION, annual meeting. New York, N. Y. May 12-15, 1941.

AMERICAN SOCIETY FOR METALS, Western Metal Congress and Exposition. Los Angeles, Calif. May 19-23, 1941.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS, semi-annual meeting. Chicago, Ill. May 19-21, 1941.

AMERICAN PETROLEUM INSTITUTE, mid-year meeting. Fort Worth, Texas. May 19-23, 1941.

AMERICAN IRON & STEEL INSTITUTE, general meeting. New York, N. Y. May 22, 1941.

AMERICAN ELECTROPLATERS' SOCIETY, annual convention. Boston, Mass. June 9-12, 1941.

EASTERN PHOTOELASTICITY CONFERENCE, semi-annual meeting. Cambridge, Mass. June 12-14, 1941.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, summer convention. Toronto, Ont., Canada. June 16-20, 1941.

AMERICAN SOCIETY OF HEATING & VENTILATING ENGINEERS, semi-annual meeting. San Francisco, Calif. June 16-20, 1941.

HEATING, PIPING & AIR CONDITIONING CONTRACTORS NATIONAL ASSOCIATION, annual meeting. San Francisco, Calif. June 16-20, 1941.

AMERICAN SOCIETY FOR TESTING MATERIALS, annual meeting. Chicago, Ill. June 23-27, 1941.

New Arc Welding Electrodes

Three new shielded-arc electrodes, Types W-30, W-83 and W-93, for specific types of arc welding work have been announced by the *General Electric Co.*, Schenectady, N. Y. All three types are heavily coated and will operate on either d.c. or a.c.

Type W-30 is an A.W.S. E-6012 all-position electrode, especially designed for automotive and piece-work industries where high currents are desired for high-production speed on lap or fillet welds.

For job welders or manufacturers engaged in the fabrication or repair of cast iron, the Type W-83—an all-position electrode—is ideally suited. Type W-93 is specially designed for building-up steel surfaces to resist wear from shock, abrasion and rolling impact.

Infra-Red Lamps for Baking Finishes

Three new infra-red heat lamps have been placed on the market by the *Birdseye Div. of Wabash Appliance Corp.*, Brooklyn, N. Y. Two of the lamps are clear, for use with gold-plated or Alzac reflectors, but the third requires no separate reflector since it is built with its own reflector lining sealed inside This silver reflector lining will keep its heat reflecting value for the 6,000-hr. life of the bulb, it is said.

Filaments of infra-red lamps operate at lower temperatures than incandescent lamps used for lighting, and the infra-red radiant energy is developed at wave lengths that have high penetration—a feature that is especially important in the baking and drying of lacquers, paints and enamels.

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HELP WANTED: Graduate metallurgist engineer with minimum of five years' experience in ferrous and non-ferrous foundries for research and control work. Reply to this ad must contain full information as to experience, age, references and salary desired. Box MA-10.

POSITION WANTED: Graduate metallurgist wishes to change positions. Now employed by tool, alloy and stainless manufacturer. Experience in physical and metallographic laboratories and in investigational work on hot and cold working of high stainless and heat resisting alloys. Thorough knowledge of heat treating and metallography with relation to applications of high speed steels. Sales work considered. Box MA-11.

An

INDEX

to the contents of

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for 1940

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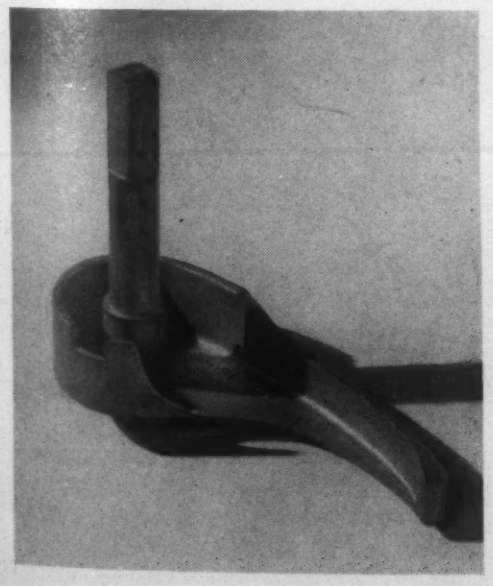
METALLURGICAL ENGINEERING

shop notes

Avoiding Inserts in Die Casting

by B. E. Sandell
Stewart Die Casting Div.,
Stewart Warner Corp.

Inserts are often cast in place in die castings, especially when the inserted piece must be stronger or harder than the metal die cast around it or is of such shape that it cannot well be formed by casting. (See the article "Spherical Pivot Formed in Die Casting" in METALS AND ALLOYS for March, page 319). The use of inserts, however, slows the casting cycle because of the extra time required to place the insert in the die; also, the insert must usually be made by another and sometimes a rather expensive process. For these reasons, inserts should be used only when they accomplish results that cannot be obtained otherwise except at a sacrifice of economy.



Designers who may have used inserts to advantage in certain die cast parts sometimes forget that there are cases in which a given result is secured at lower cost by a design in which the entire piece is die cast and the insert avoided. It is not unusual, for example, to apply an insert as a shank for a handle when the shank is subjected to torsion and must fit some mating part, as on a square or spline. This accomplishes the desired result as to performance and is certainly the best construction in some instances, but there are other cases in which the shank or extension can be cast with the square or spline along with the remainder of the piece, thus doing away with an insert and saving considerable expense.

Such an instance in which an insert can be avoided is the illustrated flushhandle for a toilet tank. As the photograph shows, the handle and shank extension are integral. Both are formed from zinc alloy, with the end of the shank cast square to fit a mating part.

A similar shank of steel could have been applied as an insert, but its cost, with the squared end, would have added considerably to the total cost. In steel the shank would have been stronger and harder, of course, but would have been subject to red rust, whereas the integral die-cast shank is not subject to red rusting and has adequate strength, as well as sufficient hardness.

To form a square, splined or serrated end on a steel or other wrought rod involves a considerable expense, but to do so on a die casting usually adds only a slight amount to the cost per piece. The die-cast extension usually can be made as large in diameter as required to have the necessary torsional strength, even though it would not have the same strength as a wrought pin of equal diameter properly anchored in the die casting.

To shrink oil-hardening steel, heat to the high side of the correct hardening range; remove and let the temperature drop to about the critical; and then quench.

—*Heat Treating Hints,*
Lindberg Engineering Co.

High-Melting Tin Solders

by C. E. Homer
Tin Research Institute, Inc.

The need often arises for solders that melt at a somewhat higher temperature than the usual tin-lead alloys and that have greater strength at elevated temperatures.

There are two tin solders that are sometimes used for service at relatively high temperatures. One contains about 5 per cent silver and the other about 3-5 per cent antimony, the remainder in each case being tin. Both have greater strength at higher temperatures than the tin-lead solders, and their creep properties are particularly good.

The temperature at which melting commences is 433 deg. F. for the tin-silver alloy. For the tin-antimony alloy it is 455-464 deg. F., depending on the antimony content. (For the conventional tin-lead alloy the corresponding figure is 361.4 deg. F.) Both solders can be used for dipping or for bit-soldering, but it is necessary, of course, to keep the working temperature some 90-110 deg. F. higher than for ordinary solder. This is particularly important with the tin-antimony alloy, which is likely to crumble and appear brittle if the iron is not hot enough. Provided that sufficient heat is applied, both solders flow well and give sound joints.

In addition to these two commercially available alloys, we have used experimentally an alloy containing 5 per cent antimony, 2 per cent cadmium, and the remainder tin. It is stronger than either of the others mentioned and begins to melt at approximately 446 deg. F. For bit-soldering it is quite easy to use, provided that the iron is hot enough, and it may also be used for dipping baths. It is, however, not quite so fluid as the tin-antimony and tin-silver alloys and when used for dipping the surplus solder does not drain off the articles so readily.

Visual Sorting of Scrap

by P. J. Dunbar
Westinghouse Lamp Division

Molybdenum, tantalum, stainless steel, and nickel scraps can be identified and separated positively and quickly by characteristic color tinges appearing on the different metals under daylight fluorescent lighting.

Sheet molybdenum and tantalum, especially, look alike under normal incandescent light, and cannot be separated by visual inspection. By segregating the scraps into small piles and lighting them with a single 24-in. daylight fluorescent lamp in a concentrating reflector, the tantalum can be identified instantly by its apparent bluish hue, while molybdenum retains its characteristic metallic color.

The method is so foolproof that these materials are now sold separately with a purity guarantee, where formerly valuable tantalum pieces were interspersed with the rest of the mass which had to be salvaged and sold as mixed molybdenum and tantalum scrap. The illustration shows sorting under fluorescent light being carried out at the writer's plant.

Recently from salvaged molybdenum having a value of about $700 in its pure state, an additional $100 worth of tantalum was recovered through this use of fluorescent lighting.

More About Tube Bending

by Herbert Chase

Excellent results in tube bending are now being secured by the use of alloys of bismuth containing lead, tin and cadmium (such as "Cerrobend", produced by Cerro de Pasco Copper Corp.) as described in these columns last August, page 227. Some added details on the use of such tube-filler alloys are presented herewith.

These bismuth alloys are used primarily because of their low melting point, 160 deg. F., as this facilitates handling and makes it possible to remove the alloy from the tube, after the latter has been bent to the required shape, by merely heating with steam or hot water. The alloy is employed extensively in preparing tubes (especially aluminum alloy tubes) for use in aircraft where many bends are usually required.

No one knows better than an editor how hard it is to write, but even so the editors earnestly solicit your contributions to this department. Payment will be made for all original material that is published.

The tubing is commonly heated above 160 deg. F. so that the molten alloy poured into it will not cold-set during loading. When a heated tube is ready to be filled, one end is closed with a stopper, made of hard wood or rubber and having a slight taper. After the molten alloy has been run in, the tube is plunged, closed end first, into water; this cools the bismuth alloy quickly and results in a fine grain structure, said to be ductile and easy to bend.

Tubes of 52 SO aluminum alloy with a wall about 0.050 in. thick are much used in aircraft and are subjected to careful inspection to guard against pin holes, thin spots and weak seams, as failures may result in serious accidents. In this connection, the bismuth alloy will find its way through the smallest pinhole or crack, even though these may be invisible to the eye because burnishing or other working has covered them with a thin layer of metal. Also, the bismuth alloy expands slightly when it solidifies and cools; this expansion is not sufficient to injure a sound tube wall, but it will reveal a thin spot, by causing a blister to occur at that point, or cause a weak seam to split.

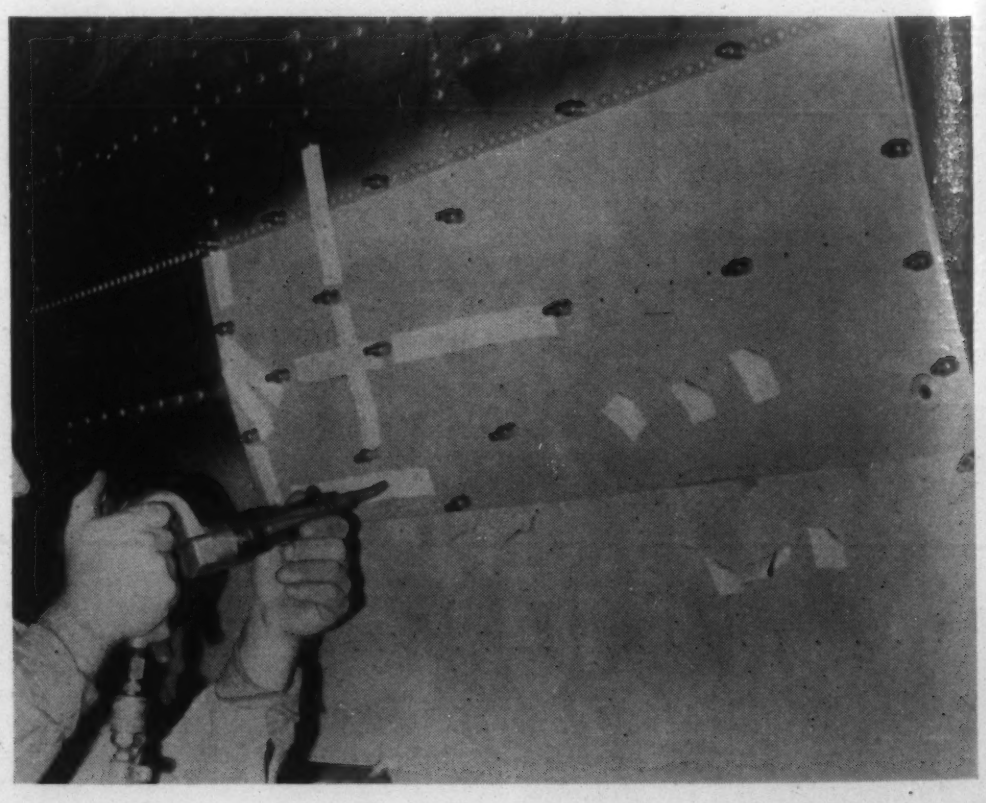
Application is not confined, of course, to aircraft tubing, but is of special importance in thin wall tubes which must be bent without flaws. Some instrument tubes with walls as thin as 0.0035 in. are bent readily by the use of bismuth alloy. A tendency to "tin" the tube or to alloy with the metal of the tube may be avoided by applying a light lubricating oil to the tube before the molten alloy is introduced.

Suction can be employed to draw the molten alloy into tubes that are too small in diameter to allow of convenient filling by pouring. It is claimed that tubes that have been plated with nickel or chromium can be bent without flaking of the plate.

Some work is reported to have been done in bending open rolled sections without rippling or distortion (other than that desired) after the metal is embedded in bismuth alloy in a suitable mold. In such work, as well as in tube bending, the alloy is reclaimed, of course, and is used repeatedly.

An Aid in Aircraft Riveting

by W. E. Mayers
Industrial Tape Corp.



Aircraft wing and fuselage structures are widely fabricated by riveting, in spite of the inroads of the spot welding process. One minor source of delay in riveting is the frequent attention the operator has to give to individual rivets that have become loosened or dislodged from their pre-placed positions before riveting.

To speed the work of riveting airplanes, industrial adhesive tape is now being used by many large aviation companies—including Grumann, Curtiss-Wright, Brewster, and Glenn Martin—to hold the rivets in position.

In addition to merely inserting the rivets in their holes, the operator who precedes the riveter covers them with strips of tape, as illustrated. Unhampered by loosened or dislodged rivets, the riveter can do his job considerably faster.

Metallurgical Engineering Digest

FERROUS AND NON-FERROUS

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4. Testing and Control

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5. General

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1 Production OF METALS, MILL PRODUCTS, CASTINGS

Blast Furnace Practice, Smelting, Direct Reduction and Electrorefining. Open-Hearth, Bessemer, Electric-Furnace Melting Practice and Equipment. Melting and Manufacture of Non-Ferrous Metals and Alloys. Soaking Pits and other Steel-Mill and Non-Ferrous-Mill Heating Furnaces. Steel and Non-Ferrous Rolling, Wire Mill and Heavy Forging Practice. Foundry Practice, Furnaces, Equipment and Materials. Manufacture of Die Castings.

1a. Ferrous

Bessemer Steel

A Composite

There is no evident let-up in the growth of interest in the Bessemer process of steelmaking, so long an unnoticed (though never unimportant) part of our steel production picture. In our January issue, p. 70, the economic status of the acid Bessemer process in America and methods of dephosphorizing acid steel were reviewed. Additional advances are reported in papers presented before recent meetings of the A.I.M.E.

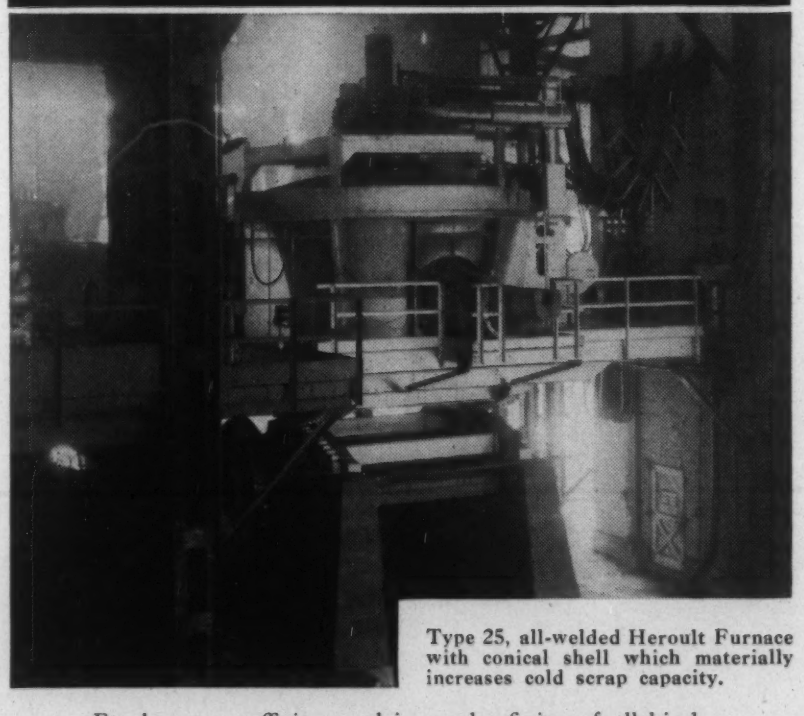
The "flame control" system developed by Jones & Laughlin Steel Corp. for the better control of the Bessemer process is discussed by H. K. WORK ("Photocell Control for Bessemer Steelmaking", *Am. Inst. Mining & Met. Engrs., Tech. Pub.* No. 1300, 1941, 19 pp.). Older attempted methods of control and observations with spectroscopes are reviewed. Spectra of the Bessemer flame at different times during the blow are shown, which indicate that during the latter part of the blow carbon is burning with a luminous flame.

In the method of control finally adopted the entire flame is imaged on a photocell and the radiant energy falling on the cell is plotted as a function of time. Filters are used so that the sensitivity of the photocell is approximately the same as the human eye. During the first half of the blow the energy received by the cell is small, but as the silicon is removed during this period and the carbon then starts to burn, the energy received rises to a maximum.

At the end of the blow, when the carbon is almost completely eliminated, the energy drops sharply. When the energy drops to a certain amount, the blow is completed and the vessel is turned down a certain number of seconds afterwards. Data are given to prove that "flame control" decreases rejections and increases yields. The nitrogen content of Bessemer steel was found to increase linearly with blowing time.

E. E. MCGINLEY & L. D. WOODWORTH of Carnegie-Illinois Steel Corp. ("A Study of Modern Bessemer Steels," *Am. Inst. Mining & Met. Engrs.*, Preprint, 20 mimeographed pp.) give plant data on Bessemer steels. Tensile strength data on both open-hearth and Bessemer steels show that for the same carbon content the strength of Bessemer steel is 15,000 lbs./in.^{2} above

Heroult ELECTRIC FURNACES



Type 25, all-welded Heroult Furnace with conical shell which materially increases cold scrap capacity.

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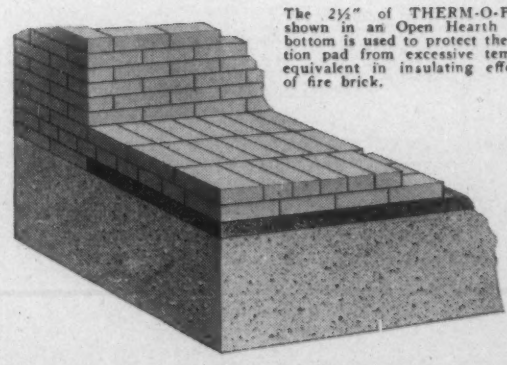

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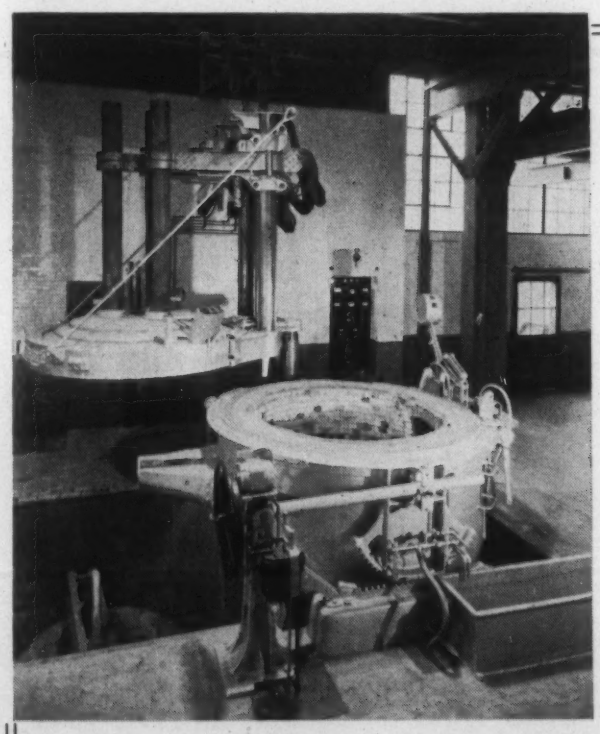

USE MOORE RAPID *Lectromelt* FURNACES for MELTING REFINING SMELTING

Illustration shows top charge type LECTROMELT furnace with roof raised and rotated to one side to permit quick charging with drop bottom bucket.

LECTROMELT furnaces offer the rapid and economic means for the production of plain carbon and alloy steel ingots and castings as well as gray and malleable irons. Top charge and door charge types are both available. LECTROMELT furnaces are built in standard capacities from 25 pounds to 100 tons. Write for details.

PITTSBURGH LECTROMELT FURNACE CORP.
Foot 32nd St. **Pittsburgh, Pa.**

that of open-hearth steels. For the same strength the open-hearth steel must have 0.15% more carbon than the other steel.

The impact resistance of the two types of steel is approximately the same when they have the same tensile strength. Billet preparation costs are correlated with teeming temperatures and it is shown that these costs increase as the temperature varies from 2890° F. in either direction for capped steels; and that the same is true when the temperature varies from 2860° F. for rimmed steel. No correlation was found between nitrogen content and teeming temperature. JLG (1a)

Extra-Hard Iron Castings

A New Process for the Manufacture of Hard Castings ("Ein neues Verfahren zur Hartgussherstellung") K. Knehans & N. Berndt. *Tech. Mitt. Krupp, Forschung. Ber.*, Vol. 3, Dec. 1940, pp. 275-278. Descriptive.

Hard castings are ordinarily produced in the foundry by using a charge with a high carbon content. This may require the use of special (and usually more expensive) pig iron.

The new process consists in providing the required carbon not in the charge but by using a fuel in the cupola that contains more carbon than foundry coke—specifically petroleum coke, which is much harder and denser than foundry coke, and has less than 0.8% volatile constituents and very little ash (0.3% as against 9-10% in ordinary coke). The carbon content of petroleum coke is 98%, with little sulphur—0.5% max. as compared with about 1% in foundry coke.

The regular coke need not be entirely replaced by petroleum coke, but only to about 25%. Experiments over a period of several years have shown that cast iron melts made with such fuel are equivalent in composition and behavior to the best melts made with the usual coke. The castings have a somewhat higher carbon content (3.64 as against 3.46) and greater hardness, 73 shore as against 67 shore. Ha (1a)

Pouring Steel Ingots

"The Influence of Turbulence upon the Structure and Properties of Steel Ingots." L. Northcott. *J. Iron & Steel Inst.*, Adv. Copy, May 1941, 41 pp. Investigation.

Seven steel ingots were cast by different methods, which were selected as offering different conditions of turbulence of the molten metal in the mold. The methods were: (1) bottom casting, (2) top casting, a single stream down the center of the mold, (3) with a multi-hole tundish, (4) in a sand mold with a single stream, (5) a single stream near one side of the mold, (6) top casting, stirring with a bar after casting, and (7) casting in a sloping mold.

The macrostructure, chemical segregation and mechanical properties of the ingots were studied. Further information on the influence of the casting method was obtained from a number of small composite non-ferrous alloy ingots, in the preparation of which a red alloy was poured first and was immediately followed by a white alloy of similar density and melting point. Knowledge of the distribution of the stream in the mold was then obtained by examining the distribution of different-colored metal in the ingot.

The casting method offering least turbulence was the multi-hole tundish. In order of increasing turbulence this was followed by bottom casting, top casting with a single stream down the center, with a tilted mold,

with a single stream near one side of the mold, and the poker-stirred methods. The structure of the tilted-mold ingot was very unsymmetrical; the lower side down which the stream was poured was composed of small equi-axial crystals while large columnar crystals grew from the opposite face. The stirred ingot showed a pronounced banded structure, the bands being approximately parallel to the middle of the ingot.

The sand-mold ingot was characterized by excessive piping, due partly to the penetration of the skin first formed by the liquid on the inside. The ingot had a coarse primary crystal structure and pronounced inverted "V" segregation. The ingot cast with a single stream near one side of the mold showed a patchy form of inverted "V" segregation. In general, the inverted "V" segregate showed a strongly dendritic structure as compared with the nodular structure of the purer metal on either side of the segregate.

Observations and theoretical considerations indicate that under completely non-turbulent conditions of casting the primary structure of the ingots would have been almost wholly columnar. The distribution of carbon and other elements is influenced by the method of casting, particularly by those processes making use of a non-axial stream. JLG (1a)

Ferro-Alloy Quality

THE EVALUATION OF FERRO-ALLOYS ("Untersuchungen zur Beurteilung von Ferrolegierungen") H. SIEGEL. *Stahl u. Eisen*, Vol. 60, Dec. 12, 1940, pp. 1125-1131. Research.

The fusibility and composition of various lots of ferro-alloys including ferro-tungsten, ferro-molybdenum and ferro-vanadium were investigated. The fusibility of a ferro-alloy can be approximated by a fusibility test with a blow-torch.

Two forms of ferro-tungsten were observed in the same consignment—very fine-grained dense lumps, lower in carbon and higher in tungsten, and porous coarse-grained lumps with large blow holes, higher in carbon and lower in tungsten. The latter (porous) type was more fusible.

Very interesting micrographs are shown of the structure and type of inclusions in the ferro-alloys. Inclusions of ferro-molybdate were identified as dark brown in color, molybdenum trioxide as yellowish white, and molybdenum dioxide as violet.

Three types of inclusions were also identified in ferro-vanadium. These were a "skeleton" type, probably a eutectic of alumina and vanadium trioxide; spherical inclusions, probably alumina silicate; and very fine inclusions, probably alumina. Such inclusions in ferro-vanadium usually go up to the slag when the ferro-alloy is added to the steel, but under certain conditions some of the inclusions may be held by the steel. SE (1a)

Blast Furnace Refractories

"MEMORANDUM ON BLAST FURNACE REFRACTORIES." LOUIS A. SMITH (Jones & Laughlin Steel Corp.) *Blast Furnace Steel Plant*, Vol. 29, Jan. 1941, pp. 63-65. Review.

As a means of checking disintegration of blast furnace linings, consideration should be given to the use of high-fired super-clay bricks for the 20-30 ft. next above the mantle, with perhaps a less expensive variation of the same from that point up to the bottom of the wearing plates. The desired brick is made from selected Missouri flint clays, all ingredients properly grain-sized, bonded, formed, and burned to have better refractoriness than is now available in the regular furnace bricks.

In addition, there would be good structural strength, low permeability and better abrasion resistance, reheat values, and non-spall characteristics. In the zone immediately above the mantle, the bricks should be of the same general type as for the top, but with lower permeability and better refractoriness.

Super refractory bricks should be used in the full thickness of the lining only for the first 12-15 ft. above the mantle. Beyond that, regular furnace bricks can be used in the half of the lining next to the shell. Under certain conditions, hard burned second quality bricks might be used in the shell half of the lining at the stock-line. Also, regular bricks could be used next to the shell clear down to the mantle.

With present-day temperature-resistant cements, it would seem logical that any hard burned structurally strong brick, laid with a 1:4 cement-grog mortar should be cheaper and as good as regular "top" quality brick, in the wearing-plate zone. The author strongly recommends that mortar for all bricks from mantle to stock-line be a heavily grogged fire-clay of high heat quality. Its grain size should be 30 mesh, but finer may be needed in certain cases.

Building the bottom 10-15 ft. of lining tight against the shell appears to be best insurance against shrinkage effects, cracks in lining, disintegration, and hot spots. With fire-brick linings, the use of so much refractory inside the line of bosh coolers is questioned, when it is known that it is slagged off in the first 2-3 weeks' operation.

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In Germany, carbon blocks or rammed carbon plastic with cooling water flowing over the outside surface is successfully used in the bosh. MS (1a)

Sources of Hydrogen in Steel

ABSORPTION AND ESCAPE OF HYDROGEN IN STEEL MAKING ("Aufnahme und Abgabe von Wasserstoff bei der Stahlherstellung") S. VON HOFSTEN, B. KALLING, F. JOHANSSON & O. KNÖS. *Stahl u. Eisen*, Vol. 60, Dec. 5, 1940, pp. 1101-1107. Original research.

To study the change in hydrogen content during the course of open hearth heats, samples were taken from the furnace with a new sampling device. The amount of hydrogen in the steel was found to depend on the hydrogen content of the fuel gas, the hydrogen content of the furnace atmosphere, the protective effect of the slag, and the temperature. Particularly in basic heats higher temperatures favored more hydrogen absorption.

The hydrogen in the charge as rust, oil, etc., generally escapes by the time the heat is melted. When the carbon has dropped to about 0.2-0.3%, the hydrogen present with the original charge is practically all eliminated. However, hydrogen that may be introduced during the refining, as moisture absorbed with burnt lime, moist ore, leaky cooling tubes, etc., may remain in the steel. Hydrogen introduced later, *e.g.* as moisture in the ladle lining or by thickly tarred molds, may have a greater effect on the steel than hydrogen present in the furnace.

The results indicated that in the electric furnace the hydrogen content was lower than in the open hearth. In induction furnaces, very low hydrogen contents were obtained. Acid slags gave better protection against hydrogen absorption than basic slags. Toward the end of the heat, basic furnace atmospheres contain about 2-3% H_2, acid furnace atmospheres about 1%. In Bessemer melts, the hydrogen content depends mainly on the moisture content of the air blast. SE (1a)

Open Hearth Steelmaking Slags

A Composite

One of the peculiarly American approaches to open hearth steelmaking problems has been the large amount of work done in this country on slag control as a production tool. Some of the papers presented at the recent annual A.I.M.E. meeting are evidence that this subject is still live material for investigation.

Thus, KARL L. FETTERS & JOHN CHIPMAN ("Equilibria of Liquid Iron and Slags of the System CaO-MgO-FeO-SiO_2", *Metals Tech.*, Vol. 8, Feb. 1941, 13 pp.) give results of an experimental study of equilibrium between liquid iron and slags at steelmaking temperatures. The melts were made in a special induction furnace under an atmosphere of nitrogen. Temperatures were determined with tungsten-molybdenum thermocouples.

The oxygen content of metal in equilibrium with the slags was found to depend upon temperature, the relationship being parallel to that previously reported for the simple Fe-O slags. The oxygen content of the metal at 2900° F. is shown as a function of slag composition. The distribution ratio is by no means constant. At equilibrium the ferric oxide is not entirely reduced to ferrous oxide (FeO).

The solubility of MgO in liquid FeO in equilibrium with metal is shown for the range 2550°-3275° F. The distribution of sulphur between slag and metal is not greatly affected by temperature, but is very dependent on slag composition. Although detailed analyses of the molecular compositions of the slags could not be made there is some evidence for the existence of orthosilicates and monoferrites in the liquid slag.

ERIC R. JETTE, O. B. ELLIS & JOHN CHIPMAN ("Effect of Temperature and Basicity Upon Equilibra of Liquid Steel and Basic Oxidizing Slags", *Am. Inst. Mining Eng., Tech. Pub.* No. 1321, 1941, 9 pp.) give other data on iron-slag equilibria. Particular attention is paid to the manganese constant and the distribution of oxygen between slag and metal.

Finally, "Research Problems Relating to Steelmaking Processes" compiled by the Committee on the Physical Chemistry of Steelmaking (JOHN J. EGAN, Secretary) *Am. Inst. Mining Eng., Tech. Pub.*, 1941, 7 pp., lists under 4 major headings the problems relating to steelmaking that are deemed worthy of investigation. The Committee is attempting to act as a clearing house for information regarding the topics in the field that are actually being studied. JLG (1a)

1b. Non-Ferrous

Die-Casting Aluminum-Silicon Alloy

"DIE CASTING IN DTD 424 ALLOYS." E. STEVAN. *Machinery, London*, Vol. 57, Dec. 12, 1940, pp. 307-308. Practical.

The alloy DTD 424 (3-6% Si, 2-4 Cu, 0.15 Mg, balance Al) is hard to cast, due to its tendency to crack, contract unevenly, and show porosity, surface defects, and cold

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shuts. Most of these difficulties are due to its high contraction and to the fact that it is sluggish in the molten condition.

Dies must be designed with these properties in mind—wall thicknesses should be as large as possible, tolerances must be fairly large, and generous fillets must be provided. The temperature of the molten metal should never be increased over 1330°-1365° F. in an effort to increase fluidity. However, dies and cores should be kept as hot as possible—it may even be necessary to provide external heating.

The castings should be removed as soon as they have solidified to prevent their shrinking onto the cores. Gates and risers must be more generous than is usual with most other light alloys. Die dressings (sodium silicate, whitening) should be used freely, and cores should be dressed with colloidal graphite.

Because of the higher die temperatures, high quality tool steels must be used for cores (usually 18-4-1 high speed steel) and for die blocks (tungsten-cobalt-vanadium high speed steels—analysis not given). If cold chamber machines are used, the feeding chamber should be immediately behind the die, and relatively large sprues should be allowed. With suitable care, good die castings can be made of this grade.

JZB (1b)

Safety in the Light-Metal Foundry

"Bases of Safety in Light and Ultra Light Alloy Manipulation." H. Berger. *Light Metals*, Vol. 4, Mar. 1941, pp. 44-53. Comprehensive review.

[*At the present time when the use of aluminium and magnesium alloys is being rapidly expanded, there is perhaps more than the usual danger of fires and explosions attendant upon the use of light metals. This is particularly true when it is considered that much new personnel is engaged in the melting, fabrication, and machining of these materials.—A.U.S.*]

Melting Magnesium

Particular attention should be paid to the condition of crucibles used in melting. Crucibles worn thin with use are always dangerous. In the case of magnesium melting where iron crucibles are used, the iron scale formed should be cleaned out of the furnace; otherwise splashed metal may spill on the iron oxide scale and thus initiate a thermite type reaction that could easily destroy the crucible, thus releasing the bulk of the metal to react further with the scale.

The bottom of the furnace should have ports leading out so that in the event of a crucible failure, the metal will drain from the furnace. The air supply to melting furnaces should have a rapid-acting cut-off so that in case of an emergency the air supply could be stopped at once. It is not enough merely to shut off the blower; a gate valve is most satisfactory, and should be located in a safe place.

Local over-heating of the crucible may be avoided by the use of modern pot furnace design in which the hot wall principle is used. The refractory wall of the furnace is pierced with a number of holes, and the gas-air mixture burns in these holes rather than inside the furnace.

In carrying a pot of molten magnesium, it is only "safety first" to place a lid over the ladle or pot to avoid possible splashing. It is dangerous to set a crucible in tongs lying on a layer of sand; there is too much likelihood of its tipping over. It is far better to make a frame to hold the tongs so that the crucible is actually off the floor.

In magnesium alloy founding, lives have been lost owing to lack of convenient exits. If it is necessary to place a melting pot in a corner, there should also be a door in the corner. The German Magnesium Committee has recommended that there be at least an interval of 10 ft. between individual furnaces or between a furnace and a wall.

Protective Clothing.

The usual leather aprons and arm shields are of course necessary in the foundry. It is highly desirable to use quick-release fasteners on all foundry clothing. However, there is less danger of setting clothes on fire in the foundry than there is in grinding and machining, where finely divided magnesium particles (swarf) are encountered. Clothes worn in machining operations should be smooth (no-sweaters) with a minimum of folds, creases, exterior pockets, etc.

Grinder's clothing should in addition be fireproofed, shaken daily in the open air, and washed once a week. [*This last would seem to be an advisable procedure under any circumstances.*—F.P.P.] Greasy and wet clothing should be assiduously avoided. Fireproofing compounds are valueless in the presence of water. If wet grinding is done, the clothing should be dusted once an hour.

The same precautions are necessary where

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oil is encountered. It is known that a pronounced lowering of an oil's flashpoint occurs when a little magnesium powder is mixed with it. Grinders exposed to either water or oil should be fitted with high-fitting rapid-release leather aprons.

Machining and Grinding Magnesium

In massive form, magnesium alloys are not dangerous to handle; they may, for example, be safely joined by autogenous welding. However, in machining, the swarf formed should be removed frequently, and stored in metal containers with tight-fitting covers. Damp magnesium alloy swarf is particularly dangerous. Cutting emulsions are not generally recommended for machining magnesium alloys because of the fire hazard.

There is even more danger associated with the grinding of magnesium alloys than with machining because of the finer swarf formed. It is necessary to remove grinding swarf by efficient exhaust systems that utilize water sprays as well as high-velocity air. Many disastrous explosions have occurred owing to the inefficiency of exhaust systems. The main precaution to be taken is that grinding swarf be not allowed to accumulate anywhere—in cracks, in walls, on operators' clothing, or in exhaust ducts.

The air in exhaust ducts should move at the order of 100 ft. per sec. in order to insure that the actual accumulation of magnesium particles be under the explosive mixture, 30 g./m. The ducts should be smooth, short, free of sharp bends and the dust should be fully precipitated into sedimentation sumps with an adequate water spray so that there is no accumulation of dust except in the sump itself.

It is desirable that the initial high air velocity at the intake be reduced to about 26 ft. per sec. at the spray to allow the dust to become thoroughly wet with the spray. This is accomplished by enlarging the diameter of the exhaust system as the spray is reached. Ideally, the grinding machine should be arranged so that it can not be turned on without turning on the air and water.

Aluminum Alloys

While there is not nearly the danger in melting aluminum and its alloys as there is with magnesium, a crucible failure can be equally serious when the molten aluminum comes into contact with iron scale, either in the bottom of the furnace, or at the outside of the iron crucible. Here again, it is highly desirable to have a quick air cut-off independent of the blower in case of a leaking crucible, so that a thermite reaction is not aided.

Much the same precautions should be taken in the grinding of aluminum as those recommended for magnesium. A spark generated in an ineffective exhaust system can raise havoc, owing to an explosion of accumulated swarf. It is interesting to note that while the maximum *gasoline*/air explosion pressure has been found to be 7.5 atm., aluminum-dust explosions have developed pressures up to 11.6 atm. The high pressures developed in aluminum explosions are due to the great heat of oxidation of the metal. AUS (1b)

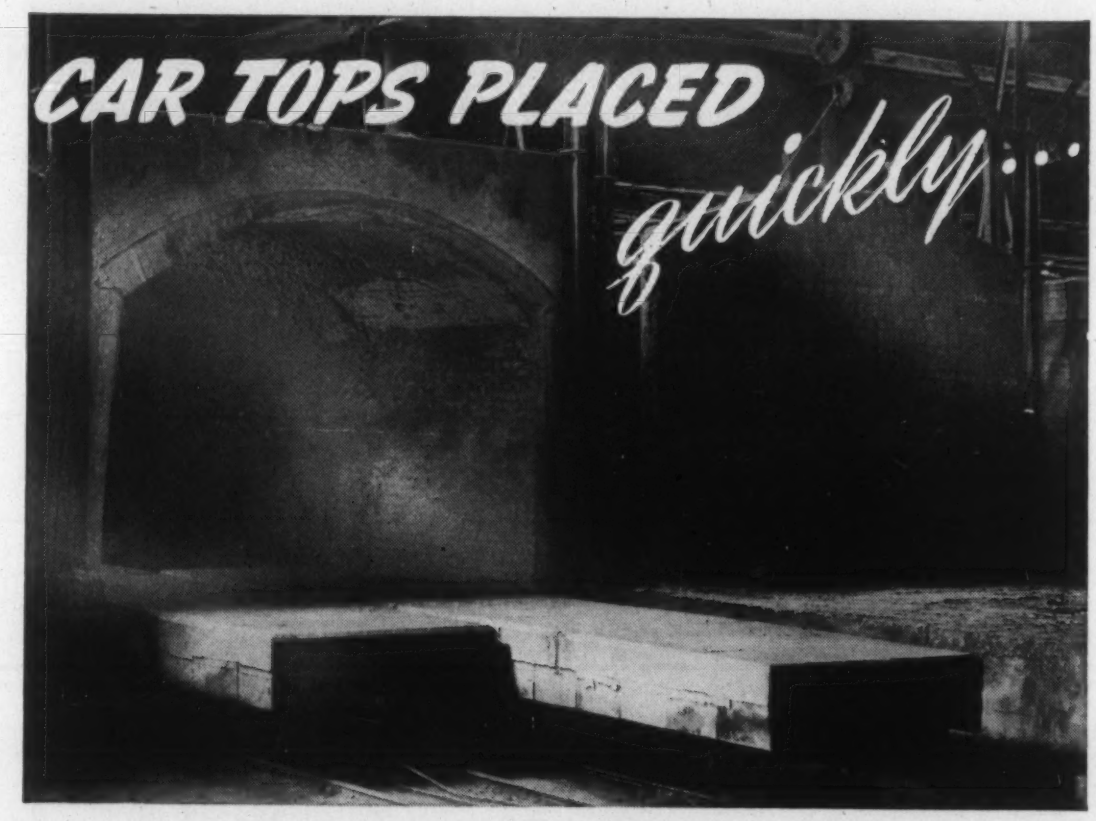
Iron Contamination in Magnesium

THE OCCURRENCE OF IRON IN PURE MAGNESIUM AND IN MAGNESIUM-MANGANESE ALLOYS ("Ueber das Auftreten von Eisen in Reinmagnesium und in Magnesium - Mangan - Legierungen") EBERHARD FAHRENHORST & WALTER BULLIAN. *Z. Metallkunde,* Vol. 33, Jan. 1941, pp. 31-34. Original research.

As contamination by iron materially reduces the corrosion resistance of magnesium, it is important to know how the former is introduced into the liquid magnesium and in what form it occurs. Published statements as to whether magnesium dissolves iron are contradictory, and iron-crucibles are used for magnesium in the industry.

The authors filled small, thick-walled, bright iron crucibles with pure magnesium of 99.9% purity 0.011-0.045% Fe, and with magnesium-manganese alloys containing 0.5, 1 and 2% Mn. A lid was welded onto the crucibles and the latter were heated to temperatures above the melting point of magnesium, followed by either water-quenching or slow furnace-cooling. The solubility was determined at over a dozen temperatures above the melting point of magnesium.

At the melting point, the solubility of iron in magnesium is only 0.026%, but it increases to 0.84% at 2200° F. With the manganese-magnesium alloys containing up to 1% Mn, practically the same results were obtained. The 2% Mn alloy dissolves considerably less iron up to about 1652° F., above which temperature the solubility approaches that of pure magnesium and of magnesium-manganese alloys containing 0.5 and 1% Mn. At the melting point of magnesium, the solubility of iron drops from 0.026% to 0.006% due to the addition of 2% Mn. EF (1b)



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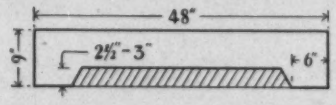

▶ *The above sketch shows how an insulating core can be employed in car tops. This core, made of Refractory* Insulating *Concrete, increases the efficiency of the refractory top and saves heat.*

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Solders

A Composite

Ordinary solders have been thrown into startling prominence by considerations of the "strategic" nature of tin, and many's the household handy-man who today squirms internally at the recollection of all the precious bright droplets carelessly spilled on the cellar floor.

The strategic and "replacement" situation with respect to solder was discussed in a feature article in our Nov., 1940, issue, p. 641. In the collection of digests presented herewith, various types of special solders, a cadmium-base "replacement" solder and solders for aluminum are discussed.

Soft Solders and Fluxes

Tinman's solder, dipping solders, soft solders for high temperature service, aluminum solders, soldering fluxes, tinning compounds and creams are all of currently great interest, according to C. W. HART ("Soft Solders and Fluxes," *Foundry Trade J.*, Vol. 64, Jan. 16, 1941, p. 40). A small proportion of antimony improves the properties of tinman's solder for most purposes. The antimony content must be carefully controlled during manufacture, however, or the solder will be sluggish and brittle. For certain duties, particularly the soldering of zinc, it is desirable to use an antimony-free solder.

All tin-lead solders commence to melt at 362° F., but they begin to lose their strength at lower temperatures. For soldered parts subjected to temperatures over 200° F. it is advisable to use a special solder having superior resistance to elevated temperatures. Two types of alloy are available. The tin-rich alloy H.T.3 melts at 455° F. It is especially recommended for electrical work since it has a high electrical conductivity and can be used with safety fluxes.

The lead-silver solders L.S.1 and L.S.2 have an even greater advantage in temperature resistance, since they do not commence to melt until the temperature reaches 580° F. They should be used only in conjunction with an active flux.

The old method of soldering aluminum involved vigorous scraping of the surface underneath the molten solder to remove the oxide. A recently-developed solder ("Fryal") has greatly simplified the tinning process.

To prevent the joint from corroding, it should be protected, for example, by paint or enamel. Protective or safety fluxes have little chemical activity. Active fluxes represent the ordinary fluxes used for sheet-metal and general soldering work. By combining an active flux with powdered solder, a compound is obtained that is far more effective than flux and solder separately applied.

The possibility of having to forego the general use of tin in British solders engages the attention of A. J. T. EYLES ("Tin Solders," *Sheet Metal Inds.*, Vol. 15, Jan., 1941, p. 50). Tin can be decreased to a certain extent in conventional solders by additions of suitable alloying additions. Thus, antimony up to 1%—in addition to improving solder properties as mentioned in an earlier paragraph—permits a decrease of up to 2% Sn in tin-lead solder.

Cadmium is a promising substitute for tin. The following cadmium solders have been tested and give good results in many applications: 90% Pb, 10 Cd; 80% Pb, 10 Cd, 10 Sn; and 90.5% Pb, 8 Cd, 1.5 Zn. The tensile strength of the lead-cadmium-tin alloy is about the same as that of 40% Sn, 60 Pb, but the ductility of the former is about twice as high.

"Hard Solders" of Aluminum

The soldering of aluminum has always been a problem to challenge metallurgical ingenuity. The use of heavily-alloyed low-melting aluminum-base solders for "hard-soldering" aluminum and its alloys is examined by H. SCHULZ ("Praktische Anwendung der Hartlötung von Al and Al-Legierungen," *Autogene Metallbearbeit*, Vol. 34, Jan. 1, 1941, pp. 10-12).

Hard-soldering of this type is preferably applied for pure aluminum (m.p. 1215° F.), magnesium-free aluminum-copper and aluminum-manganese alloys, and aluminum - copper - magnesium, aluminum-magnesium-silicon and aluminum-magnesium-manganese alloys with low magnesium-content inasmuch as the temperature difference between their melting points and that of the solder is wide enough. Not suitable for hard - soldering are aluminum-magnesium alloys of high magnesium content, pure magnesium and all magnesium-base alloys. Likewise, the precipitation-hardening aluminum alloys cannot be hard-soldered as the temperatures employed obliterate the benefits of age-hardening.

The hard solders, usually in the form of wire, have their melting points between 1000° and 1100° F. and consist of at least 70% Al alloyed with silicon, copper, zinc, tin, etc. The aluminum alloy "silumin," with a melting point of 1060° F. is particularly suitable as an aluminum solder because of its fluidity. Fluxes used with the solders should be most efficacious at about 1040° F.

The procedure is about the same as the brazing of copper and brass, and the joints should be carefully cleaned. The strength of the soldered joints is stronger than the material as fracture in tensile tests occurs in the material rather than in the joint.

The corrosion resistance of joints soldered with silumin is the same as that of a weld as the solder has only a very small potential difference in contact with aluminum and its alloys. If the corrosion resistance is to be very high, the soldered joint can be protected against access of moisture by a lacquer. The color of the joint is somewhat darker than that of aluminum, so that the joints can be polished only under certain conditions; anodizing is also not always possible, as discoloration of the joints occurs. X (2)

Electroplating of Aircraft Parts

"ELECTRODEPOSITION IN THE AIRPLANE INDUSTRY." URBAN A. MULLIN (Wright Aeronautical Corp.) *Monthly Rev. Am. Electroplater's Soc.*, Vol. 28, Mar. 1941, pp. 185-195. Descriptive.

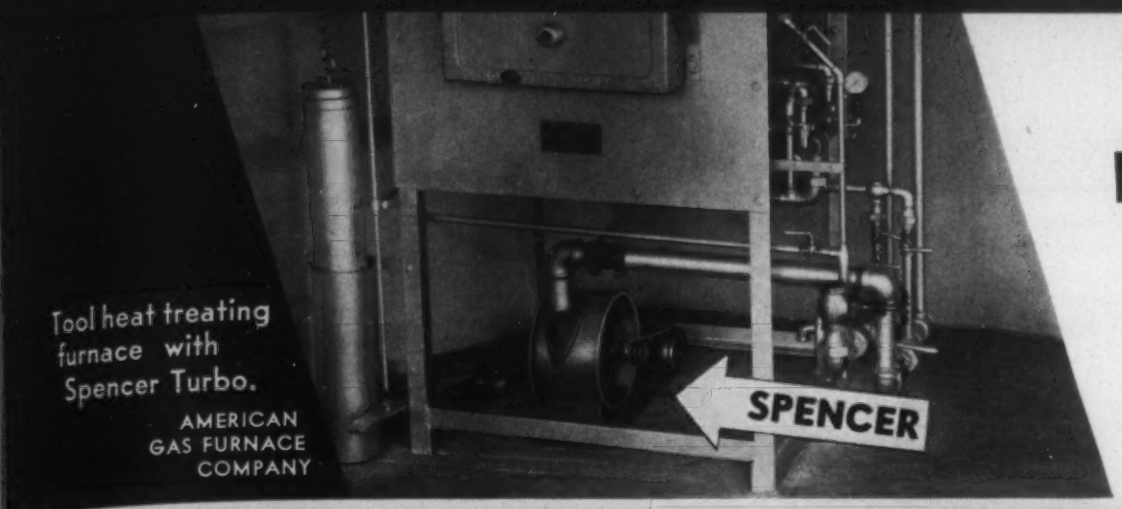
Copper plating is mainly used to prevent carburizing of the web of gears when the teeth are hardened. The gear blanks are plated with at least 0.0005 in. of copper before the teeth are cut. Gas carburizing is used and the work is then annealed and tempered.

Tin coatings are used to protect areas from nitriding. Since the nitriding is done at 975° F.—which is above the melting point of tin—only thin tin coatings (about 0.0003 in.) can be used, as the thicker ones flow onto an adjacent steel surface.

Cadmium coatings are used for protection against rust. Threaded parts are given 0.0002-0.0003 in. and exposed parts a minimum of 0.0005 in.

Silver is used as a bearing metal by depositing heavy coatings on a stainless steel backing. Chromium coatings are used where hardness and abrasion resistance is required and for building up worn tools and machine parts. Lead is deposited from a fluoborate bath on the inside diameters of bushings and bearings.

Bearing metals are corroded by acids either present in or formed from motor oils. A small percentage of indium (0.2-4.0%) diffused into the bearing metal greatly decreases corrosion. Bearing surfaces are prepared by first plating the shell with lead and then with indium equal to 4% of the weight of lead. The indium is diffused into the lead by heating at 340° F. for 2 hrs. The indium is plated from a cyanide bath, but it is believed that the acid sulphate bath has some advantages. AB (2)



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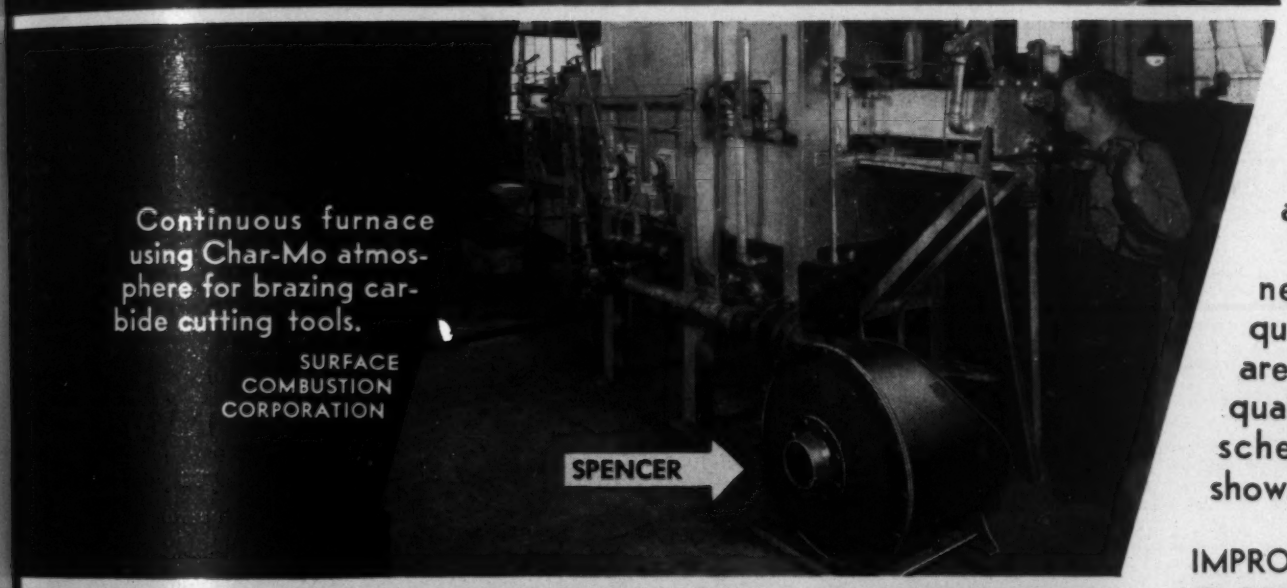

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Electric Metallizing Gun

THE METAL SPRAYING PROCESS ("Ein Beitrag zur Kenntnis des Metallspritzverfahrens") M. U. SCHOOP. *Giesserei*, Vol. 28, Jan. 10, 1941, pp. 9-10. Descriptive.

An improvement in the electric gun, which now operates 3-4 times as fast as the gas gun in spraying zinc or aluminum and 9-10 times in spraying high-melting metals, is described.

The electrodes for forming the arc are about 0.06 in. diam. The voltage is 50 v., which drops to 30-35 v. for 300 amp. when the electrodes are closed in starting. The air current blowing against the arc can have a pressure of 8-10 atm. without disrupting the arc. Although the temperature of the arc is extremely high, the evaporation of the easily melting metals is not excessive. The whole gun weighs 2.5 lbs. and is made mainly of magnesium alloy.

The electric gun is said to be particularly suitable for metallizing dies and molds for rubber, bakelite, porcelain and other materials. The gas components of the air must be considered highly active in the atmosphere of the electric arc, hence the use of inert or reducing gases is recommended. A film made of ordinary iron wire is highly rust-resistant, apparently because of nitriding by the nitrogen of the air. The hardness increased 200%, and no shrinkage of the sprayed material took place.

By using electrodes of copper or aluminum, bronze and other alloys sprays can be produced, as can chromium-nickel steel or molybdenum steels, using these materials as electrodes. The metal-sprayed film has a better adhesion, it is claimed, than one produced with the gas-operated metal-spray gun. Ha (2)

Abrasive Cutting

"CUTTING WITH ABRASIVES." R. R. WIESE. *American Machinist*, Vol. 85, Feb. 19, 1941, pp. 97-100. Practical.

Steel bars as large as 6 in. round can now be cut with abrasive wheels. Dry cutting is used for high production where fine finish is not important. Excessive heating will cause discoloration and possibly surface hardening, and this tendency can be reduced by changing the wheel to one with a more brittle grain, a softer grade, or a more open grain structure.

Correct speed is very essential. In wet cutting, lower speeds can be used with cleaner cuts and reduced wheel wear. Lower-cost rubber-bonded wheels can also be used. The coolant may be water, mild soda solution, or, for ductile metals, a light mineral oil. Submerged cutting is best for heat-sensitive steels, thin-wall copper tubing, plastics, and any application where temperature must be kept low. Rubber-bonded wheels are usually used.

Alumina is the most common abrasive, and, if the proper grain size is used, it can cut everything from aluminum to tungsten. Silicon carbide is better, however, for cast iron, copper tubing, pure copper slabs, hard rubber, plastics, and porcelain. Diamond grains are required for very hard materials such as sintered carbides.

Shellac-bonded wheels are useful for cutting tool steels in the tool room. Resinoid bonds are generally used for dry cutting, while rubber-bonded wheels are used for wet cutting. The coarsest grit and the hardest grade wheel give the maximum wheel life. The rate of feed has an important bearing on the wheel life. Detailed recommendations are given for proper wheels for cutting all types of metals and alloys. JZB (2)

Gas-Heat for Baking Finishes

"GAS FUEL FOR SHORT-CYCLE CURING OF INDUSTRIAL FINISHES." CARL P. MANN (Selas Co.) *Paper, Am. Gas Assoc.*, Mar. 1941, 5 mimeographed pp. Descriptive.

It is claimed that gas fuel possesses unusual advantages over other means of heating for the short-cycle curing of industrial finishes. The facts presented in the paper apply only to polymerizing finishes, as oxidizing and volatilizing finishes are not suited to short-cycle curing—curing times of less than 30 min.

The cardinal point to be kept in mind in all consideration of curing finishes is that curing is directly dependent on heating the work piece, and only in the degree that any curing process accomplishes this, will the process be successful. Gas fuel may be applied in the form of convection heating, infra-red ray radiant heating, or by a combination of both.

Irregularity of shape has no influence on convection heating, but in radiant heating it is important that no part of the work pieces cast a shadow over a finished part. It is of equal importance that the rays strike all finished surfaces at approximately the same distance from the radiant source, as the effectiveness of infra-red rays is very much influenced by the distance between the work piece and the energy source.

If radiant sources are located beneath the work piece in order to minimize the shadow effect, their effectiveness may be decreased

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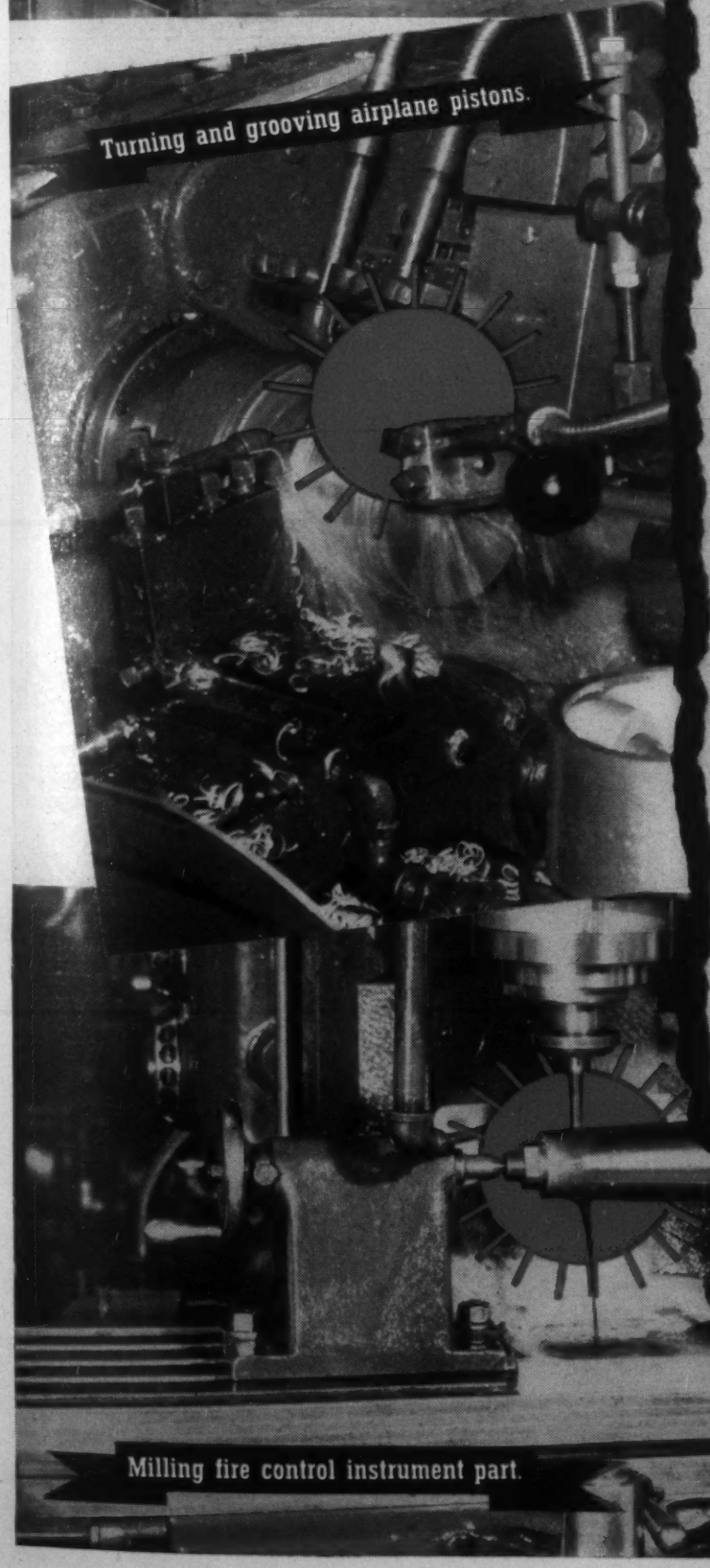

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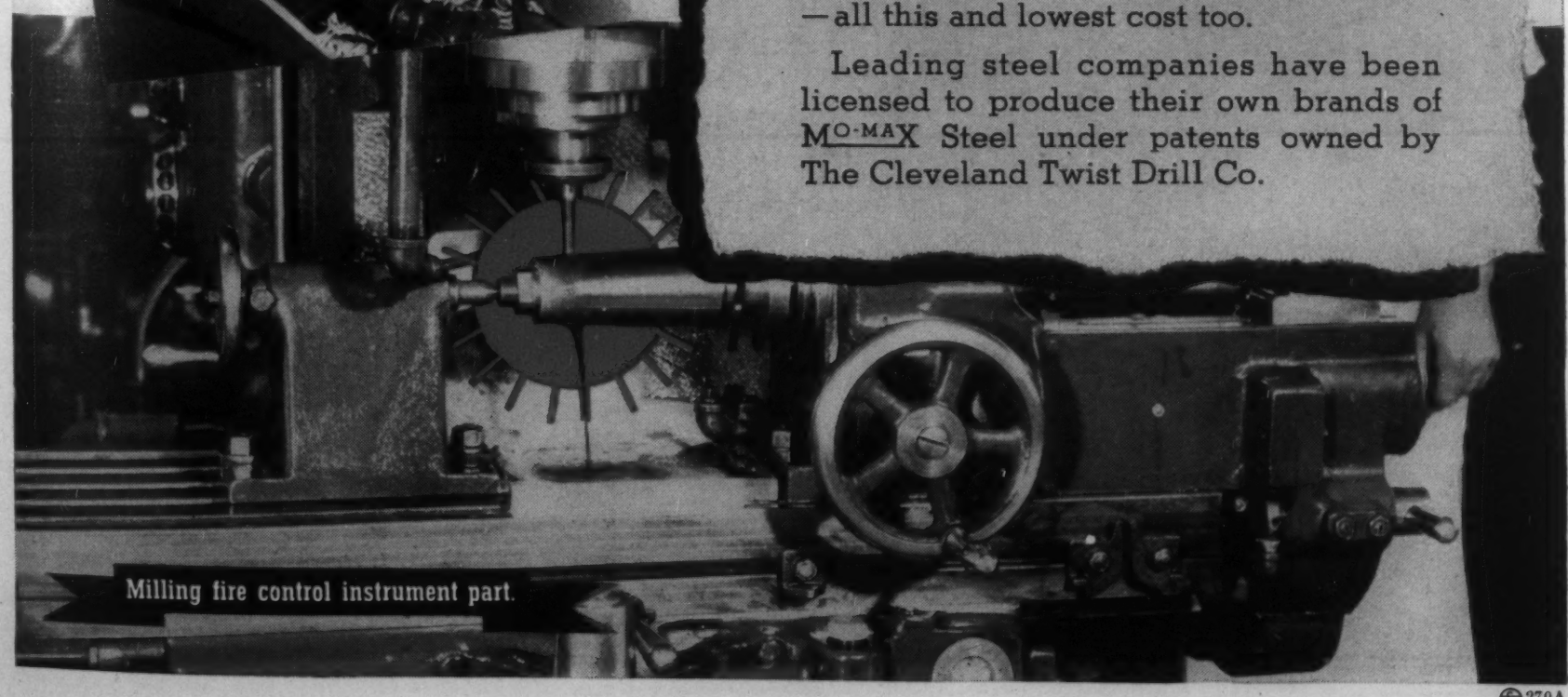

270A

due to dripping. Also, the effectiveness of infra-red ray lamps, but not radiant gas burners, will be decreased by the vaporization and condensation of solvents on the lamps and reflectors. Convection heating is entirely free of these disadvantages.

Polished or unpolished metal surfaces under finishes do not affect curing time with convection heating, but in the case of radiant heating a polished surface will require approximately 20% more time for curing than an unpolished surface. If radiant gas burners are used, and if infra red ray lamps are used the increase in curing time may vary from 9% to 45%, depending on the type and color of finish.

Infra-red ray lamp installations are less expensive and somewhat less complicated in operation; but when the production capacity of such an installation is compared with that of convection heating, we uncover "startling" facts. On the basis of the same length of oven, an infra-red ray lamp installation (using 375-watt lamps, and no preheat) producing 253 pieces/hr. will, if converted to convection heating (circulating air at 400° F. and allowing a 1-min. preheat) produce at the rate of 1480 pieces/hr., or nearly 6 times that of the infra-red ray lamps. Furthermore, if radiant gas burners are used without the interposition of glass barriers, this rate of production will be 2260 pieces/hr. without any preheating period.

The data developed point toward a combination of radiant heating from gas burners with convection heating. By circulating the products of combustion given off by the radiant burners within the oven, the curing effect of this circulated air is added to the unshielded radiant heat from the burners themselves, which combination should give a very compact and efficient curing installation. FPP (2)

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Flame Machining

"Flame Machining — Control and Applications." G. L. Walker & W. G. Sylvester (Air Reduction Sales Co.) *Welding J., N. Y.,* Vol. 20, Feb. 1941, pp. 91-100. Investigation.

The various flame machining processes as commercially used are classified as (a) flame planing for surfacing, deseaming or gouging operations; (b) flame turning for rough machining or grooving operations, and (c) flame drilling. The classification is based on the relative motion between the flame machining tip and the work, (a) being rectilinear, (b) curvilinear and (c) axial.

In order to specify proper procedures for a given operation, it is necessary to determine the interrelation of the tip size, pre-heat intensity, oxygen pressure, speed of traverse and angle of tip relative to the work piece. The velocity of the oxygen stream and pre-heat intensity can be suitably controlled through proper functional design of the flame machining tip. Data are presented in numerous curves and illustrations showing the effects of varying these interrelated operating variables.

The authors' work in determining the contours of grooves for a wide variety of settings has made it possible to form grooved surfaces with a maximum variation of 1/64 in. for any one dimension, and this performance can be repeatedly maintained. The necessary operating conditions can be selected from the graphical data to produce grooves varying from deep and relatively narrow to shallow and relatively wide.

The applications for the flame grooving process are for preparation of plate edges for welding after flame cutting to size; for rough machining; for removal of surface defects 3/8 to 1/2 in. deep in one pass; and for removal of sub-surface defects in welds and castings (as revealed by X-ray) by one or more passes of flame gouging with a groove sufficiently wide to make re-welding easily possible.

The grooving process is unlike chipping and grinding procedures in that the removal of unsound metal is assured, since defects and cracks are clearly visible as contrasting dark spots or lines respectively, in the reaction zone. The more expensive U and J grooves machined on plate edges for welds in thick plates are easily prepared by flame grooving. WB (2)

Electrodeposited Zinc Coatings

Common Features and Peculiarities of Different Electrolytic Zinc Coatings ("Gemeinsames und Besonderheiten verschiedener galvanischer Zinküberzüge") Hellmut Fischer & Hildegard Bärmann. *Z. Metallkunde,* Vol. 32, Nov. 1940, pp. 376-383. Original research.

The velocity of solution of electrodeposited zinc coatings in *N* HCl and 3% NaCl solution shows differences for coatings made from different electrolytes, depending on whether they are freshly made or used for some time. Particularly great differences were noticed with alkaline electrolytes used for bright zinc plating. After

all electrolytes have been used for some time, the same dissolution speeds during corrosion of their products are obtained, irrespective of how the zinc deposits were made.

The resistance to tarnishing of bright zinc electrodeposits is greater than that of dull deposits. The lustre of bright zinc coatings, however, could not be preserved by lacquer coatings in long-time salt water spray tests. By giving zinc coatings additional chromate films, resistance towards the corrosive effect of evaporations, mostly moist ammonia, from artificial resin materials could be insured.

Debye pictures show more or less distinct fibre textures in coatings obtained in alkaline electrolytes, but chaotic crystal orientation prevails in acid ones. Bright zinc coatings are particularly fine-grained, although the grain size is not smaller than the length of light waves. The bright lustre must thus be explained on the basis of a well-developed texture.

Coatings deposited from acid electrolytes have the coarsest grain. Zinc coatings show no tendency toward recrystallization at room temperature or up to 660° F. Deep drawing tests (Erichsen) showed more ductile bright zinc coatings obtained in acid solutions than in alkaline electrolytes; on the other hand, the latter furnished less porous coatings than the former under identical conditions of deposition. With increasing current densities, the porosity of the zinc coatings deposited in acid baths decreases.

Galvanizing steel in alkaline baths results in hydrogen embrittlement, which is practically absent in acid solutions. After removal of the zinc coating, the embrittlement persists for some time and gradually vanishes, owing to hydrogen diffusion, until the bending value of the uncoated material is finally recovered. The embrittlement of galvanized samples does not decrease at room temperature, but may be overcome by heating to 575° F.

A new method of testing the porosity of galvanic zinc coatings consists of cathodic charging with hydrogen followed by a determination of the number of bendings. EF (2)

Gas Furnaces for Shells and Guns

"Uses of Gas in the Production of Munitions, Particularly Shells and Guns for Aerial Warfare." F. Coleman Starr (Surface Combustion Corp.) *Paper, Am. Gas Assoc.*, Mar. 1941, 6 mimeographed pp. Survey.

A partial list of the operations carried out in gas-fired furnaces now in use or being built for armament production is given, and one or two individual furnaces, interesting as representing certain types of operation, are discussed.

The list does not apply entirely to ammunition for anti-aircraft guns nor to the guns themselves. A shell or shell-case for a 5 in. anti-aircraft gun might demand the same heat treatment and same furnace equipment as 5 in. secondary battery ammunition for a battleship. A 3.7 in. or 4.5 in. anti-aircraft gun might take the same furnaces as an anti-tank gun.

The list does cover furnaces designed or built or under construction for guns, shell and shell cases of 5 in. caliber and the smaller sizes. It does not include some of the other very important industrial gas applications such as heat treatment of tools, gas carburizing of light armor, heat treatment of aircraft engine cylinders, aircraft tubing, propellers, etc., although all are properly gas-fired operations and are important in the Defense Program.

The general types of furnaces listed are projectile furnaces, shell case or cartridge case furnaces, gun barrel furnaces, and furnaces for gun mounts, carriages, etc. Projectile furnaces are for forging, nosing, normalizing, hardening and drawing. Shell case furnaces are annealing furnaces. Gun barrels must be heated for forging, quenching, drawing and stress relieving. Most of the furnaces for gun mounts are for stress relief of welds.

One furnace for forging or heat treating of 5 in. shells is described. The outside diameter of the furnace casing is 23 ft. The rotating hearth is 3 ft. wide with a mean diameter of about 17 ft. The hearth is built up of fire brick piers, capped with alloy plates. This furnace has a capacity of 8000 lbs./hr. of either shells or airplane engine cylinders and a temperature range from 800°F. to 1800°F.

The furnace is direct-fired, over and under, with high pressure gas burners, and for the lower temperature ranges, the Conjecto method of firing [See Metals and Alloys, Vol. 11, June, 1940, p. MA323] for temperature uniformity. One interesting feature of this furnace is the elimination of seals. The furnace pressure in the three zones is automatically controlled and there is no apparent leakage of air into the furnace

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nor outward flow of gases, either at the full firing rate or when holding.

A typical heat treating set up for gun barrels is described. The gun barrels, for anti-aircraft guns, are from 3 in. to 5 in. caliber and are forged from blanks and rough-machined before the quenching operation.

The quenching furnace is a vertical pit type unit from 25 ft. to 30 ft. deep and about 9 ft. inside diameter. The gun barrels, singly or in groups of 2, 3 or 4, are hung from a special fitting or spider. This may be handled with the furnace cover or separately, as desired. The furnace is direct-fired with either high or low pressure burners, which are applied to insure the most uniform heat input and distribution. There are at least 3, and preferably 4 vertical zones of control.

After quenching, the gun barrels are lowered into a draw furnace, usually pit type, and in some instances the same furnace is used for drawing and quenching. While this can be done, it is obvious that at the usual draw temperatures a direct-fired unit is not as efficient as the convection type nor can the same uniformity of temperature be obtained.

After drawing and finish machining, the gun barrels are then stress relieved in a low temperature convection furnace. This is usually a car type or horizontal batch type furnace because, at the temperatures involved, the gun barrel may be supported horizontally without fear of bending. (2)

2a. *Ferrous*

Heat Treating High-Speed Steels

HEAT TREATMENT OF HIGH-SPEED STEELS LOW IN STRATEGIC [NON-GERMAN] ALLOY ADDITIONS ("Zur Wärmebehandlung von sparstoffarmen Schnellstahlen") R. VOEGELIN. *Tech. Zentralbl. prakt. Metallbearbeitung,* Vol. 50, Sept. 1940, pp. 457-460. Practical.

The Table shows the high-speed steels most commonly used in Germany at different times, and the customary heat treatments.

German High-Speed Steels

Year	Composition						Heat Treatment	
	C	V	Cr	W	Mo	Co	Hardening, °F.	Tempering, °F.
Before 1938	0.75	1	4	18	..	..	2340-2375	1040-1075
	1.30	4	4.5	14	..	..	2280-2340	1000-1040
	0.85	2	4	18.5	0.9	5	2340-2440	1075-1110
1938/1939	0.75	1	4	2	8	..	2230-2265	1000-1040
	0.80	2	4.25	5.5	4.5	..	2250-2280	1000-1040
	0.85	2.4	3.6	12.5	1.8	4.2	2265-2340	1025-1075
1939/1940	0.95	2.5	4	2.5	2.5	..	2210-2250	1000-1040
1940	0.80	1.6	4.25	9.5	0.5	..	2250-2300	985-1025
	1.35	4.3	4.25	11.5	0.9	..	2265-2320	1000-1025

The Table shows the high-speed steels most commonly used in Germany at different times, and the customary heat treatments.

In comparison with the first 3—the "classical" high-speed steels—the second set reveals a trend in 1938 to the replacement of tungsten by molybdenum, owing to the "Far East situation". During the fall of 1939, the interruption of the supply of molybdenum from the United States necessitated a reversal of this trend, so that at present German high-speed steels are likely to run toward high-tungsten rather than high-molybdenum.

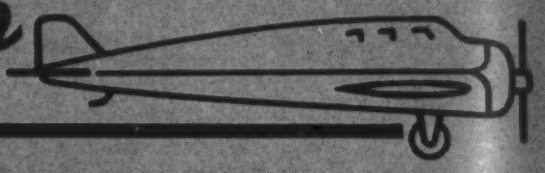
Steels low in tungsten are much more sensitive to hardening temperature. As shown by the table, the hardening temperature and also the thermal stability increases with the tungsten content.

A drastic improvement of the cutting capacity of the new steels has been achieved by forging from all 3 sides, resulting in uniformly large and well-distributed carbides. The forgings should cool in baskets suspended in the air, followed by stress-relief annealing at 1100° F. and air-cooling.

A set of 5 micrographs show the effect of quenching from different temperatures between 2175° and 2390° F. on 3 modern high-speed steels, in comparison with 18-4-1. The former show a tendency toward grain growth and more pronounced solution of carbides compared with the latter; the new steels thus require more uniform heating and accurate heat treatment.

The new steels also display a greater tendency toward surface defects, carburization, decarburization, etc. Alkaline baths (barium chloride, say) attack the iron, while acid baths (such as borax) react with the carbon. The choice is thus between decarburization on one hand and corrosion on the other. EF (2a)

Speed up



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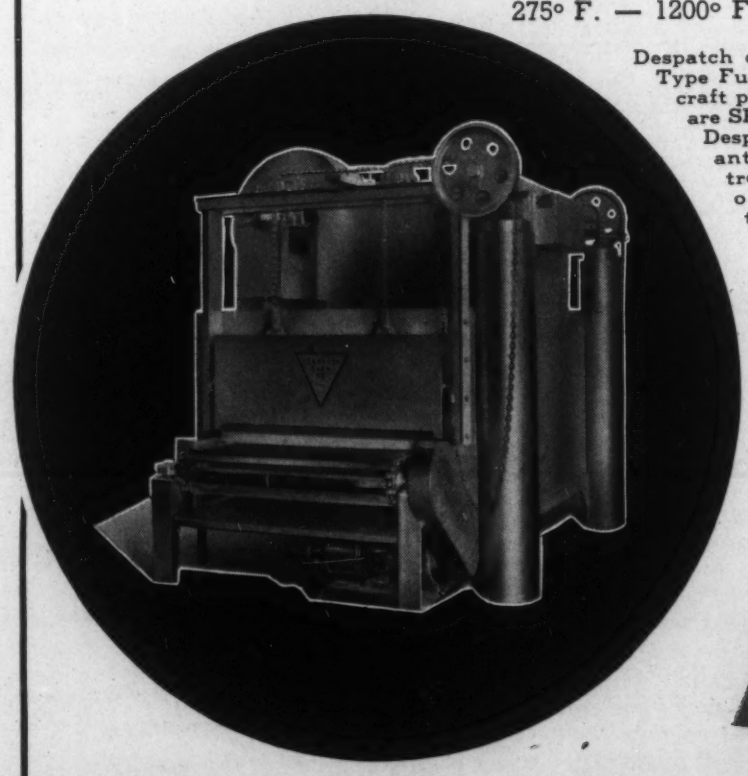

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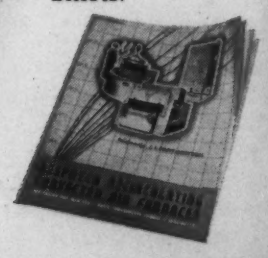

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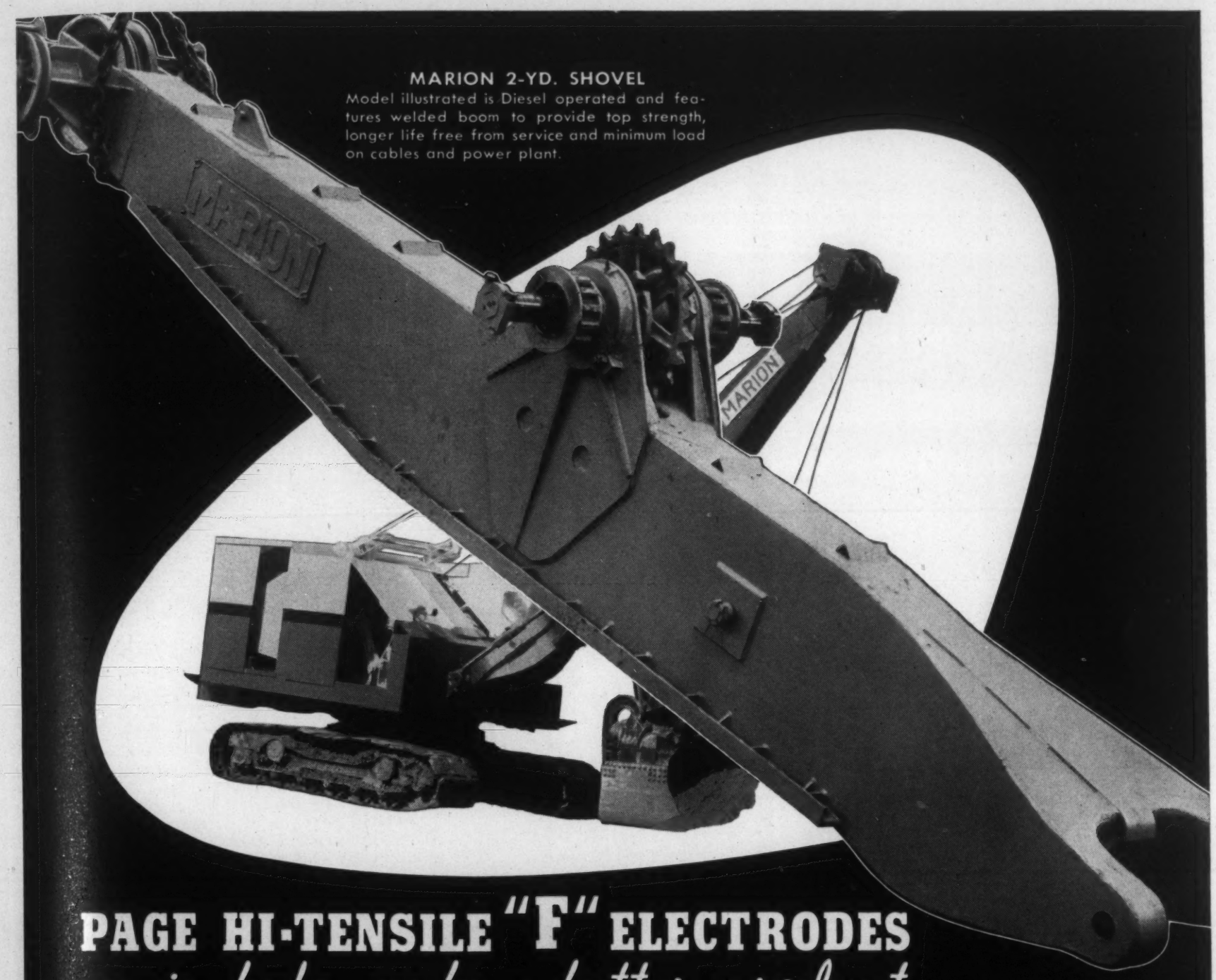

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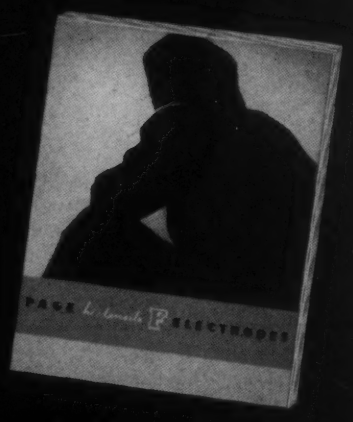

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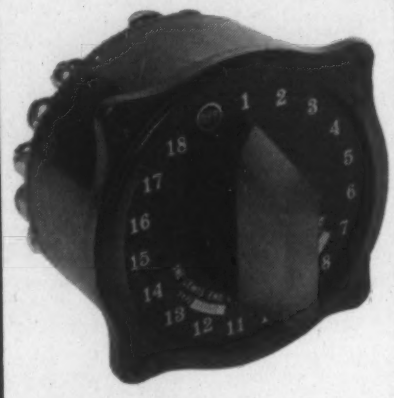

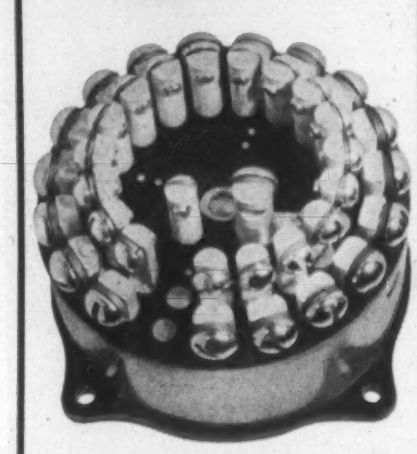

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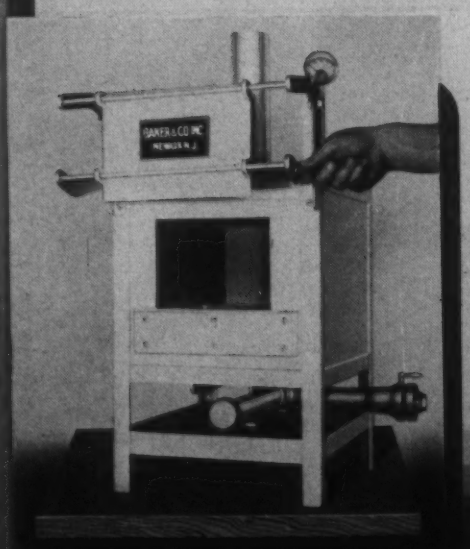

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Performance of Welding Electrodes

"Evaluating Welding Electrodes." Joseph A. Duma (Norfolk Navy Yard) *J. Am. Soc. Naval Engrs.*, Vol. 53 Feb., 1941, pp. 65-75. Research report.

Data are collected for the physical and chemical properties of 10 commercially-used electrodes to evolve a quantitative method of evaluating electrode qualities. What is most needed is a formula for relatively grading electrode performance under conditions of varying skill. The data are tabulated in detail for chemistry of core wire for 5/32 in. diameter electrode, micrographs of typical inclusions, cold worked base metal, McQuaid Ehn structures, etc.

The physicals noted for the 10 electrode coatings are (with max.-min. values): thickness differences, 0.031-0.018 in.; eccentricity, 0.005-0.001 in.; weight, in grams per linear in., 0.593-0.209; weight % of core, 24.1-8.5%; number of rods in 50 lbs., 607-540; shear value as received, 2200-633 lbs./in.^{2}; shear value for the used upper half, 2200-1140 lbs./in.^{2}; bend test values around a 2 in. pin, 13°-8° bend to cracking; bend test values to flaking, 120°-45°.

Chemical analyses for Al, FeO, MnO_2, TiO_2, CaO, MgO, CO_2, Na_2O, SiO_2 gave interesting results. Aluminum ranged from 1.35 to 0.16%, while one coating had only a trace. The TiO_2 content ranged from 20.46 to 5.34% and Na_2SiO_3 from 35.78 to 16.34%. From the chemical tests the electrodes are classified as (a) gas-shielded or (b) slag-shielded— with 8 electrodes in the first classification, 2 being high-TiO_2 types.

Of the two slag-shielded electrodes, one was a high-manganese type and the other high iron oxide. Slag properties are tabulated in terms of weight of slag, flux, slag per gram of flux (ranges from 1.75 to 1.08), slag density, fluidity and color, per cent composition as SiO_2, FeO, Al_2O_3, TiO_2, CaO, MgO and MnO. The base-to-acid ratio (calculated as the summation of the Fe, Mn, Ca, Mg, Ti oxides as against the $SiO_2 + Al_2O_3$ total) ranges from 14.2 to 1.3.

Welding tests were carried out in the vertical position since this is the position in which it is most difficult to obtain a sound, ductile weld. Welds were analyzed chemically and tested for tensile strength, yield point, elongation, Izod impact, specific gravity, number of "bird eyes" (fish-eyes, flakes, etc.), and per cent of weld-metal recrystallized. Information is provided as to arc and deposition characteristics and a merit factor or performance value for 3 different methods of calculating the factor is offered.

A relationship was found between electrode-slag and number of bird-eyes, since the basic slags tend to produce flaky or bird-eye deposits to a greater extent than acid slags. Thick slags from slag-shielded electrodes produce deposits nearly free from bird-eyes. Aging after machining of tensile specimens of weld metal resulted in a slight increase in ductility of 6 specimens and decrease of 4 specimens.

Only 4 out of a total of 40 specimens passed the Navy requirement of 22% min. elongation; the 2 slag-shielded electrodes gave these 4 acceptable specimens. The author says that "failure to meet ductility requirements is traceable to too-thick-layer deposits" (as shown in data on the extent of recrystallized metal in the weld) "to hindered contraction and shrinkage stresses resulting from the fixity of the joint, and to the presence of the defect 'bird eyes' in the fractured weld-metal—the last defect a product of hydrogen embrittlement." By

employing a weaving procedure in welding it was possible more completely to heat treat the underlying deposit and increase the ductility for one of the electrodes to 24-25%.

Performance evaluation of the electrode is thus a summary of the ductility of the deposit, workability of the electrode in sharply angular recesses, tensile strength of the deposit and excellence of its surface, and insensitivity to damaging effects of changing the current and voltage conditions during welding. Arc stability tests failed to show that aluminum and Al_2O_3 decrease the arc stability, as has been reported previously in the literature. WB (2a)

Flame Hardening with Excess Oxygen

FLAME HARDENING WITH EXCESS OF OXYGEN ("Autogen-Härten mit Sauerstoffüberschuss) E. ZORN. *Autogene Metallbearbeit.*, Vol. 34, Jan. 1, 1941, pp. 13-15. Investigation.

A number of tests were made to ascertain the effect of excess oxygen in the oxyacetylene hardening flame. It is shown that savings of about 50% in fuel can be made in flame hardening if a flame with a large excess of oxygen is used instead of the neutral flame.

An excess of 75% seems to give the best hardening depth, but even higher excesses give good penetration. In order to utilize the high flame temperature and the heat of combustion of the acetylene flame to the best advantage, it is important to make the distance between the burner and the workpiece equal to the length of the flame cone. Ha (2a)

Deep Carburizing in Salt Baths

DEEP CARBURIZATION OF CHROMIUM-MOLYBDENUM AND CHROMIUM-MANGANESE CARBURIZING STEELS IN SALT BATHS ("Tiefzementieren von Chrom-Molybdän- und Chrom-mangan-Einsatzstählen in Salzbädern") H. DIERGARTEN. *Stahl u. Eisen*, Vol. 60, Nov. 14, 1940, pp. 1027-1035. Practical.

By using cyanide-containing salt baths very uniform carburizing can be obtained at 1650°-1700° F. However, on long-time carburizing of chromium-molybdenum and chromium-manganese steels in this way to produce 0.045-0.080 in. case depths, massive carbides form at the surface; this makes grinding difficult and does not give the required strength.

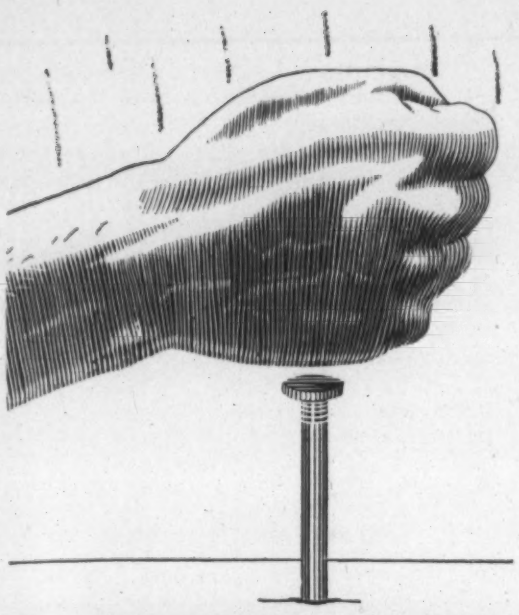
After carburizing, however, if the material is annealed for 20 min. at 1780° F. in a neutral salt bath, the heavy carbides will be dissolved. The final surface hardness is not diminished by this treatment. However, cracks occurred in this material, evidently flakes caused by hydrogen absorption from the carburizing and annealing baths.

The remedy was to use baths free of moisture and hydrogen, and to slow-cool after carburizing and annealing. SE (2a)

"Fish-Eyes" in Welds

"MICRO-FISSURING IN MULTIPLE-BEAD LOW-CARBON STEEL WELDS." JOHN L. MILLER & LEWIS R. KOYAC (Ill. Inst. Tech.) *Welding J., N. Y.*, Vol. 20, Feb. 1941, pp. 114s-119s. Research report.

"Fish-eyes," "bird-eyes," "cat's-eyes," etc. are microfissures in weld-metal that lower its tensile properties, especially ductility. Plates of fire-box steel (0.17% C) were welded under various conditions and ex-



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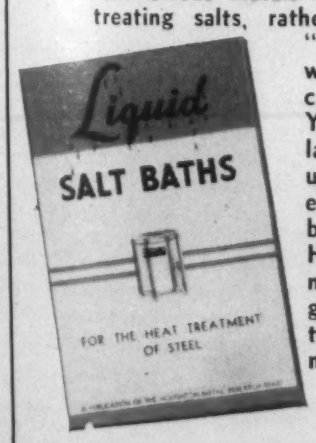

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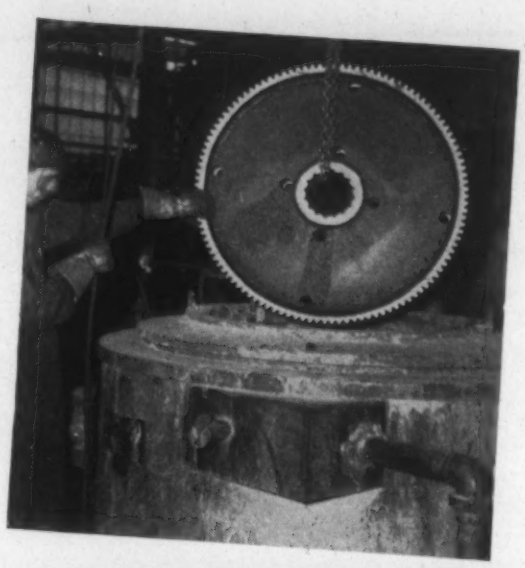

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amined metallographically in the as-welded and in the heat-treated conditions.

Micro-fissures were found in welds made at 0° F. for the entire series of multi-layers but none was found in welds started at 0° F. in which the interpass temperature was allowed to build up. The fissures were confined to recrystallized zones of weld metal and terminated abruptly at the junction with the coarse-grained cast structure. Heat treatment at 1200° and 1700° F. did not affect the number or type of fissures.

A second set of welds were made in 2 in. thick, hot-rolled mild steel. A standard electrode and a high-manganese electrode were employed for comparison, using 45 passes per weld in order to give maximum recrystallized weld metal. Interpass temperature was 70°-130° F. for cast bead. The welds were examined as-welded and after heating to 800°, 1200° and 1700° F. In every case in this second set micro-fissures were found. An automatically controlled weld was also made and found to contain regularly distributed, small micro-fissures.

The stresses resulting from contraction of the weld on cooling are considered to be responsible for micro-fissuring as indicated by the absence of the phenomenon when the weld was made with increasing interpass temperature. The planes of the micro-fissures were perpendicular to the welding direction and appear to be intercrystalline in nature. The authors believe the occurrence of recrystallization and of the stress cycle at the same time induce the intercrystalline rupture because of the low cohesive strength of the grain boundaries at the high temperature.

Hydrogen thus cannot be the sole or primary cause of micro-fissuring (as maintained by Zapffe and Sims—see METALS AND ALLOYS, Feb. 1941, p. 206) since actual failures should then be developed most readily at the lowest temperatures and be therefore transcrystalline, distributed alike throughout fine- and coarse-grained weld metal.

The conclusions are that thermal gradients, and allotropy involving the simultaneous formation of ferrite and austenite (of different plasticity), account for fissures and intercrystalline fracturing. Impurities at the grain boundaries and non-metallics are sometimes associated with the fissures. WB (2a)

Brazed Joints in Steel

"THE EFFECT OF THE PHYSICAL STATE OF STEEL UPON THE TENSILE STRENGTH OF BRAZED JOINTS." F. C. KELLEY (Gen. Electric Co.) *Welding J., N. Y.*, Vol. 20, Feb. 1941, pp. 96s-102s. Research.

The type and composition of steel being brazed has considerable influence on the strength of the joints. Various steels—low-carbon, cold-drawn Bessemer stock; 0.35% C; 3½% Ni steel; drill rod, etc.—were given various heat treatments before brazing; tensile tests were made on the material after heat treatment and after brazing.

Stress-strain curves of brazed joints of Bessemer cold-drawn steel variously heat-treated approximated the shape of similar curves for the unbrazed material; the tensile strength, yield point and proportional limit are slightly lower than for unbrazed steels. Per cent elongation and reduction in area are very much less than the latter. The strongest joints were those in which the copper did not pull out the grains of steel in rupturing.

Brazing of 0.35% C steel in pure dry hydrogen was unsuccessful—a result that does not check with commercial experience; in industrial practice the surface of 0.35% C steel is oxidized, removing the carbon therefrom, and the oxide is subsequently reduced to iron, which is the ideal surface for copper to wet. However, after decarburizing the surface with wet hydrogen and hydrogen-oxygen mixtures, the steel was successfully brazed. Very similar results were obtained for the physical properties of blank and brazed specimens. The drill rod and 3½% Ni steels were successfully brazed after a similar decarburizing treatment.

A saturated solution of nickel nitrate [$Ni(NO_3)_2$] in water may be applied to the hot surface of decarburized steel, and this, during heating, oxidizes the iron surface and leaves nickel oxide in finely divided form over the surface. Nickel oxide is easily reduced to nickel by hydrogen at 400°-575° F. and catalyzes the reduction of iron oxides and removal of carbon. Wetting of the surface is greatly facilitated by this procedure and the physical properties of the resulting brazed joints are high. WB (2a)

Cemented Carbides for Cutting Tools

PROPERTIES OF SINTERED CARBIDES AND THEIR RELATION TO WEAR RESISTANCE ("Eigenschaften von Hartmetallegierungen und ihr Zusammenhang mit der Verschleissfestigkeit") WALTER DAWIHL. *Z. Metallkunde*, Vol. 32, Sept. 1940, pp. 320-325; discussion p. 326. Research.

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is much less conspicuous when machining steels. The addition of titanium carbides to tungsten carbides has increased the wear resistance for steel-cutting applications. As no plausible explanations have been offered for the difference in behavior of cemented carbides towards cast iron on one hand and steel on the other, the author studied the behavior of tungsten carbides with and without titanium carbide.

Gray cast iron of 200 Brinell hardness and 2 steels of 78,000 and 135,000 lbs./in.^{2} tensile strength were used. The tool wear over a great range of cutting speeds was experimentally determined. These "stand-up time" (*Standzeiten*) curves indicate that the wear is not purely a matter of mechanical abrasion, as shorter tool lives may be obtained at lower cutting speeds than at higher.

Tests showed that the tungsten carbide tool containing no titanium carbide has a higher bending strength, thermal conductivity and resistance to high-frequency vibrations. No differences in the strength at 1100°-1300° F. were found between both kinds of sintered carbides; however, the scaling losses at 1100°-1650° F. were reduced to ¼-⅔ of their original values by adding titanium carbide to tungsten carbide.

Steel cubes free from oxide were pressed against both types of carbide faces at elevated temperature in hydrogen. Higher temperatures are required to form a "weld" with cemented carbide cubes containing titanium carbide; or, at the same temperatures, lower stresses were required for separating the steel from carbides containing titanium carbide. This lower "adhesive strength" (*Klebefestigkeit*) is considered to be an important factor in the better wear of tungsten + titanium carbide mixtures—*i.e.* the formation of a built-up edge and the subsequent breaking-off of sections of the tool is less pronounced.

At low cutting speeds the mechanical stresses (such as vibration) predominate and the carbide tool without titanium carbide performs better because of its better heat conductivity, bending and vibrational strength. At high cutting speeds, the straight tungsten carbides show a greater tendency toward built-up edges and thus to wear. At the lowest cutting speeds, the tool temperature rise is not high enough to form a built-up edge, which is also suppressed by using a coolant, or, as in the case of cast iron, by the formation of a short chip.

At small feeds, the temperatures at the wear surfaces are lower and the mechanically stronger, plain tungsten carbide tool is superior even in the case of relatively high speeds. As no built-up edge is formed with non-metallic materials such as glass, resins, carbon, etc., the above deductions do not hold and the titanium-free carbide should be employed. The latter should also be used for room-temperature drawing of wire, while at higher temperatures, the addition of titanium carbide is beneficial.

EF (2a)

2b. Non-Ferrous

Forming Aluminum Alloys

"Shape Forming." C. C. Bain & J. T. Weinzierl (Aluminum Co. of America) *American Machinist,* Vol. 85, Feb. 19, 1941, pp. 101-103; also "Embossing, Coining and Stamping." J. F. Weingierl & C. D. Myers. *Ibid.,* Mar. 5, 1941, pp. 154-156. Practical.

The material to be used for tools for forming aluminum alloys depends on the number of pieces to be produced. Castings or machined steel can be used for small runs, while hardened and polished tool steel is necessary for long runs.

In designing, the problem of metal spring-back in the higher elastic limit alloys must be taken into consideration. Radii required for 90° bend for all common aluminum alloys are given. In forming in press tools, lubricant is used on the female die side. Medium-grade engine oil diluted with kerosene is satisfactory for average forming, but tallow coating is required for severe forming or for shaping heavy-gage aluminum.

Embossing is the production of raised figures in relief; the embossed section has a characteristic uniform thickness. Coining is a method by which the design on a set of molds is impressed into the plane surface of a blank. Stamping refers to the cut lines of figures resulting from the impact of a stamp, having a relatively sharp projecting outline, upon a smooth surface.

The usual tool for all three processes consists of a punch and die, both made of hardened tool steel. In the case of stamping tools, however, only the punch on which the design has been cut in relief is hardened; the die (or anvil) is smooth and usually of a mild steel. Roller dies are sometimes very practical.

In embossing, rubber may be used for the female die; for example, aluminum foil may be decorated by passing it between a steel roll having the design cut in relief and a smooth rubber-faced contacting roll.

The use of oil or other lubricant should

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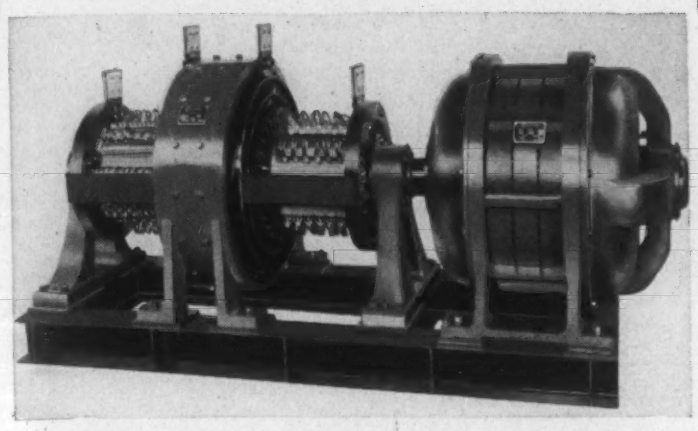

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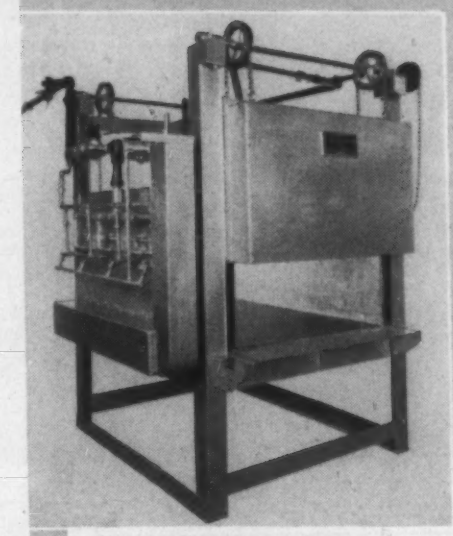

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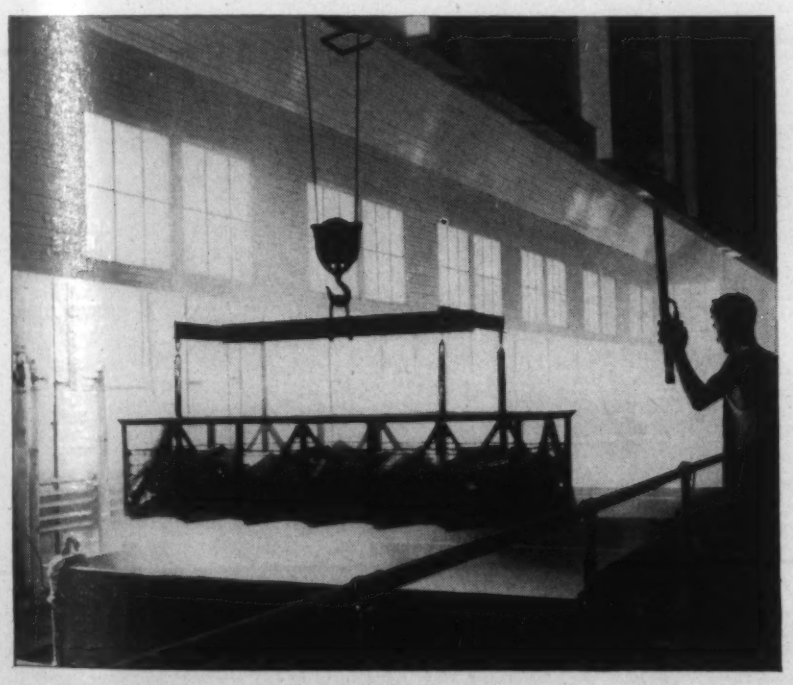

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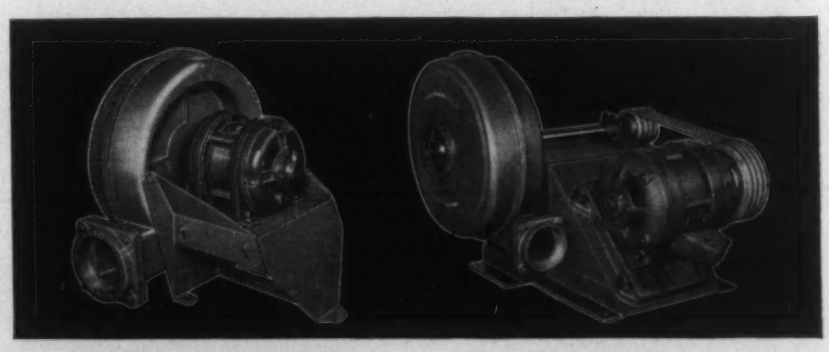

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JZB (2b)

Annealing Aluminum Alloys

THE EFFECT OF MANGANESE ON THE RECRYSTALLIZATION OF ALUMINUM AND SOME ALUMINUM ALLOYS ("Ueber den Einfluss des Mangans auf die Rekristallisation von Aluminium und einiger Aluminiumlegierungen") WALTER BUNGARDT & EUGEN OSSWALD. *Z. Metallkunde*, Vol. 32, Nov. 1940, pp. 368-375: Extensive original research.

Aluminum of 99.9% purity and 23 aluminum alloys (analyses given) were submitted to recrystallization tests in (a) the precipitation-hardened and (b) the solution-annealed states. Four of the alloys represent commercial material, while the rest were specially melted in an induction furnace, forged, rolled and heat-treated. The beginning, degree and end of recrystallization after 30-min. annealings was determined by X-rays and photomicrographs.

In 6 binary aluminum-manganese alloys containing between 0.1% and 1.54% Mn, the recrystallization temperature range was shifted to higher temperatures than with pure aluminum. The first 0.2% Mn is most effective since this is within the limit of solubility. Hardly any change takes place at higher manganese concentrations. The beginning of recrystallization is practically the same for pre-treatments (a) and (b) but the recrystallization is finished at a lower temperature for (b), *i.e.* solution annealing narrows the recrystallization temperature range.

The addition of 2-9% Cu to binary aluminum-manganese alloys lowers the recrystallization temperature range of aluminum-copper-manganese-silicon alloys appreciably, as compared with binary aluminum-manganese alloys. An addition to 0.32% Fe is even more effective than silicon.

Aluminum-manganese-copper alloys with 0.4-1.0% Mg_2Si recrystallize at about the same temperature as straight aluminum-manganese-copper alloys, owing to the low solubility of Mg_2Si. Generally speaking, the temperature-raising effect of one or more alloying elements may be partly or completely abolished if a metallic compound is formed with the elements already present and if the base metal shows no solubility for such compound. Thus, in commercial duralumin alloys, the recrystallization temperature range is raised but slightly by the addition of 0.1-1.0% Mn.

The most pronounced effect of manganese on the recrystallization temperature range was observed in binary aluminum-manganese alloys while all the more complex alloys recrystallize between pure aluminum and the binary aluminum-manganese alloys. The recrystallization range was narrowed —though to a varying degree—in all cases for pretreatment (b) as compared with (a).

Evidently defying all laws derived from observations on other metals, aluminum-magnesium-manganese alloys with 2.33 Mg, 1.18 Mn, 0.47 Si, 0.37 Fe and 0.12 Cu recrystallize at a lower temperature than aluminum of 99.9% purity. Magnesium more than offsets the recrystallization-temperature-raising effect of manganese. In some alloys, manganese raises the "critical deformation" to higher percentages, in others it suppresses the formation of coarse grain on recrystallization completely.

EF (2b)

Welding Copper Alloys

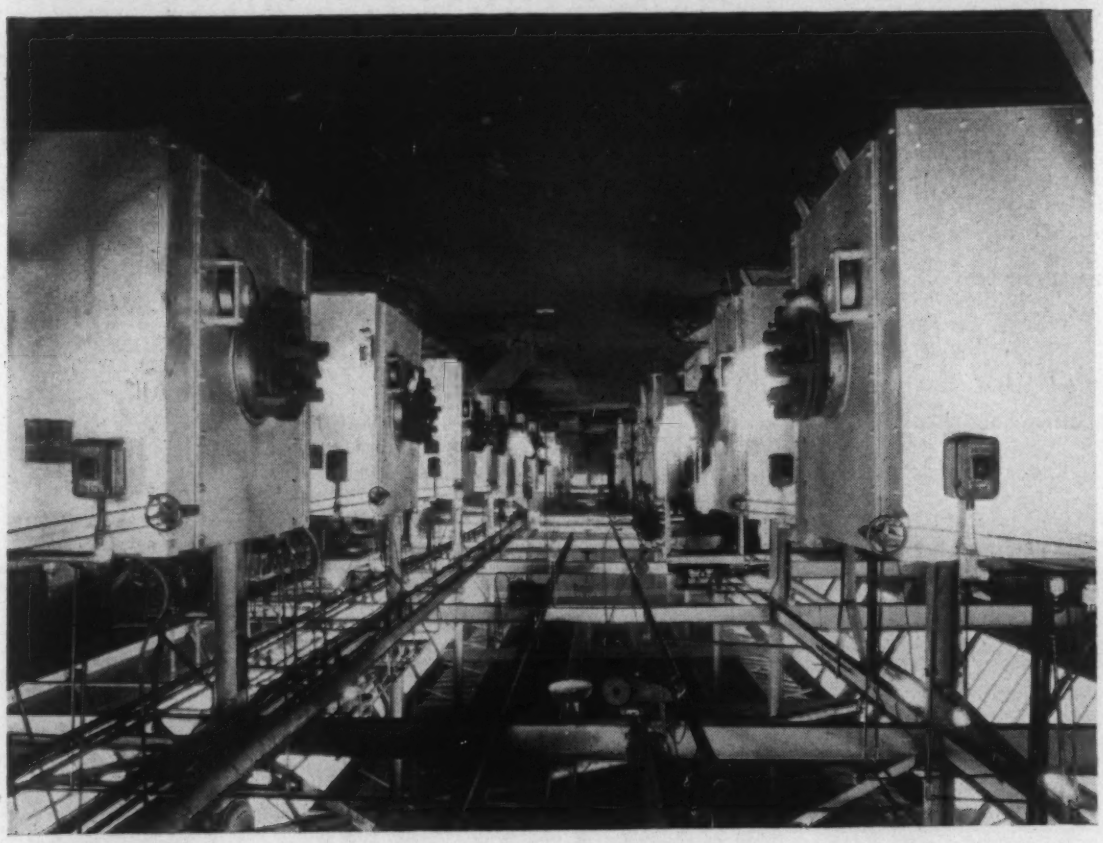
"WELDING OF COPPER-RICH ALLOYS." AGRICOLA. *Sheet Metal Inds.*, Vol. 15, Feb. 1941, pp. 205-213. Practical.

Alloying additions decrease the two main difficulties encountered in welding pure copper: high thermal conductivity, and reactivity with and solubility for gases. However, there is an increased risk of cracking due to the presence of brittle or low-melting-point phases.

Most welding of brass is by the oxy-acetylene process. Special welding rod material with small amounts of deoxidizers (silicon, phosphorus), manganese and sometimes silver, nickel or iron is used. Some of the alloy additions found in brass (aluminum, chromium, lead) are detrimental, either because of difficulties in fluxing or increased tendency towards cracking. Brass must be fluxed; a common flux consists of borax with about 30-50% NaCl. The flame should be definitely oxidizing to form a thin film of zinc oxide which prevents vaporization and loss of zinc.

Preheating to 575°-725° F. is desirable on sheets over 1/8 in. Cracking in brasses containing alloying additions like lead is reduced by avoiding cooling stresses. It is not necessary to hammer the weld metal during cooling or to hot work it as is the case with copper.

The carbon arc is little used for brass; it offers the advantage of higher welding speeds, but considerable zinc volatization is encountered. The metallic arc is un-



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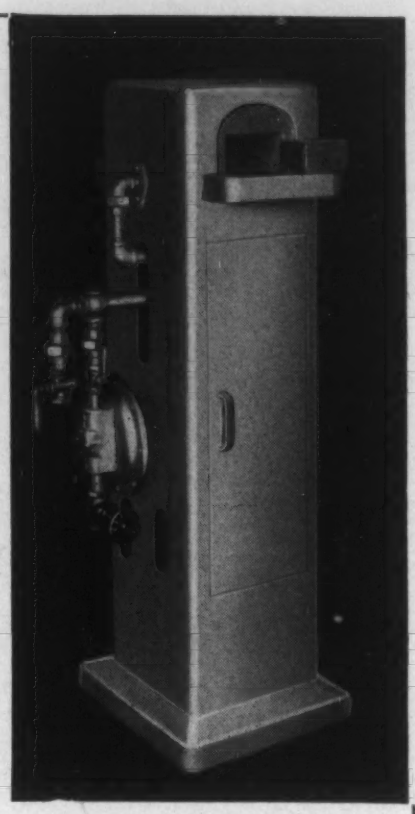

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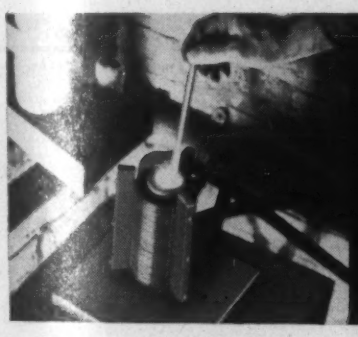

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PERMO PRODUCTS CORPORATION, CHICAGO

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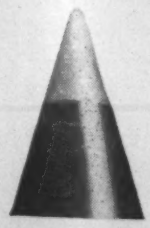

Macrophotograph of a Permo point: the light colored tip is formed of the alloy produced in an Ajax-Northrup Furnace.

Power for the furnace is furnished by a 35 KVA Ajax-Northrup high frequency converter which changes 60 cycle power to 50,000 cycle power.

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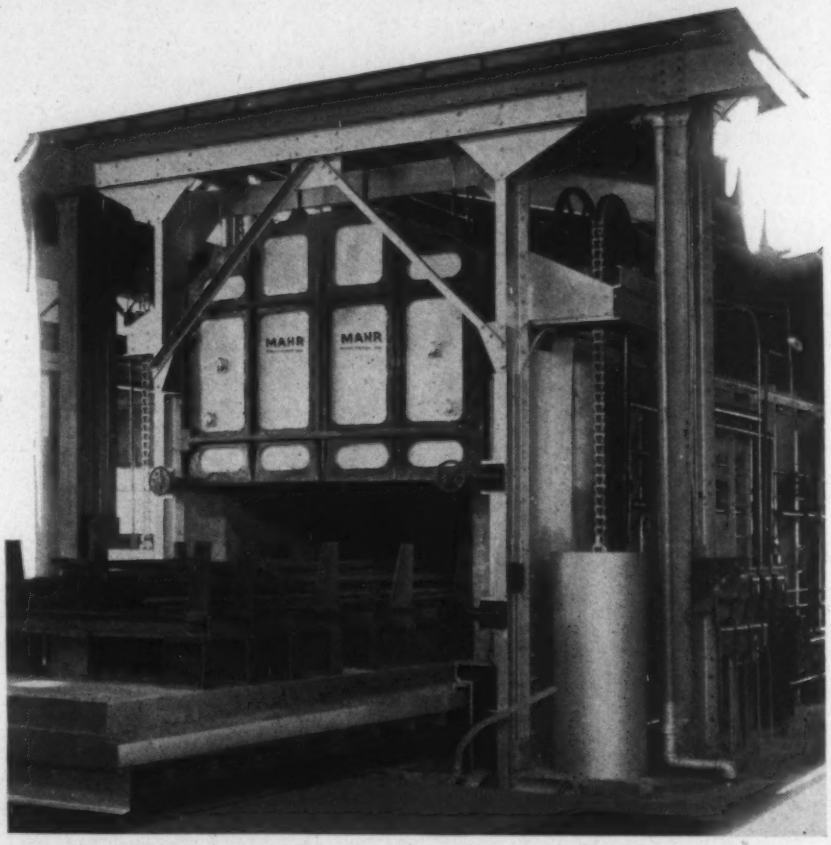

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suitable, due to zinc volatization. Spot welding is not too reliable, again because of loss of zinc.

In welding *tin bronzes,* difficulties with zinc volatization are, naturally, not encountered, but the formation of the lower-melting-point beta phase may lead to cracks or porosity; segregation and coring are common in bronze welds. Welding rods for oxyacetylene welding are of the same composition as the parent metal, except for higher phosphorus. The usual flux is borax with additions of some halide salt such as NaCl. There is little trouble with liquation up to 5-6% Sn, but alloys with higher tin should be cooled rapidly. The welding flame is neutral, except for leaded bronzes, when it should be slightly oxidizing.

Metallic arc welding is not used to any extent, but the carbon-arc is employed a great deal. Resistance welding gives strong welds, but both the bronze and the electrode tips must be carefully cleaned to prevent sticking.

In welding *nickel-silver,* the chief difficulties are loss of zinc, formation of refractory oxide layer, and a tendency to hot shortness. Gas absorption and porosity increase with rising nickel content. Arc welding is used only when a 60-40 brass electrode with additions can be employed. Oxyacetylene is generally suitable, but the weld metal must be chosen so as to have the same color as the parent metal. The flux is principally borax.

Pre-heating is not necessary, but a strictly neutral flame must be used. Annealing gives greater homogeneity (such treatment is useful in food equipment and similar applications involving corrosion), but strength is seldom more than 50% of the unwelded material. Good resistance welds are possible, but zinc is likely to cause "spitting" and porosity.

Cupro-nickels give trouble in welding because of the hard black oxide formed, the ease with which gases are absorbed, and the tendency to hot shortness. Metallic arc welding with heavily-coated electrodes is possible, but most commercial welding is by the oxyacetylene process. Welding rods for cupro-nickels should contain manganese and silicon to reduce porosity. A flux is required, and a slightly reducing flame is recommended. Hot shortness may be overcome by the use of suitable jigs. These alloys can be readily spot or seam welded.

Silicon bronzes have only one notable disadvantage from the welding viewpoint—their tendency to hot shortness at temperatures near the melting point. No flux is necessary, but if one is used a considerable portion of chloride is necessary in addition to borax, while sodium fluoride (NaF) is useful in attacking SiO_2.

Both the carbon- and metallic-arc processes are used. In metallic-arc welding, the electrode must be heavily coated to overcome the effect of the silica film on the metal. Spot and seam welding characteristics are very good, but surfaces must be carefully cleaned.

The main difficulty with *aluminum bronze* stems from the thin film of aluminum oxide formed. No flux is absolutely satisfactory, but a good proportion of NaCl, KCl, NaF or KF is always required; alloys with over 5% Al are very difficult to weld under any conditions. Cleaning of surfaces before welding is important. In oxyacetylene welding, the flame should be slightly reducing. Metal-arc electrodes must have heavy flux, but are not used commercially at present. The carbon-arc is satisfactory. These alloys are easy to spot weld if the oxide film is removed.

Cadmium-copper, silver-copper, etc. present no difficulties. Beryllium-copper is hard to weld due to the formation of beryllium oxide, which no flux appears to remove. JZB (2b)

1000 reliable joints per hour!

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Machining Zinc-Base Die Castings

"Machining Zinc Alloy Die Castings." N. J. Zinc Co. *American Machinist,* Vol. 58, Mar. 19, 1941, pp. 259-261. Useful data compilation.

Zinc die casting alloys are relatively soft (37-113 Brinell) and are free-machining. Since castings are close to finished size, little machining must be done.

High speeds and light cuts give the best results. High speed steel tools can be used, but Stellite and cemented carbides are better on long runs and where the highest accuracy and finish are required. Most machining is done dry, but lubricants are recommended for some operations and for most deep-drilling and tapping. Recommendations for drilling, tapping, threading, reaming, turning, milling, spot facing, broaching, shaving, sawing, grinding, and polishing are given.

Swaging is done cold, but not below 70°F. and increases the tensile strength up to a reduction in area of 40%. Riveting can be done but not below 70°F.; rivets are generally cast integral with one section of two mating die castings. Castings that cannot be easily cast to the desired shape can be bent or formed after casting. Mild heating may improve the ductility but is generally not required if the castings are over 70°F. JZB (2b)

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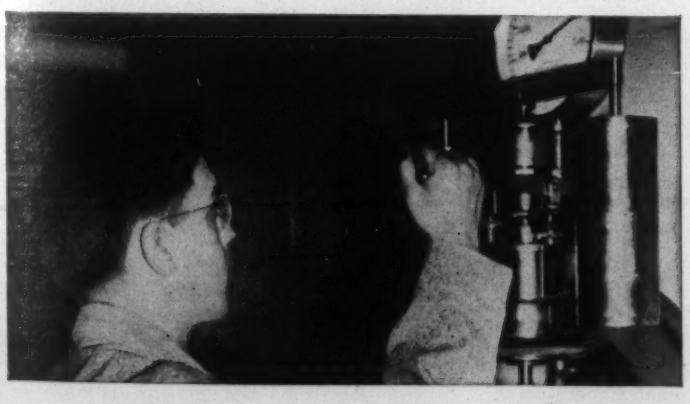

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3 Design and Applications

METALS, ALLOYS, METAL FORMS ENGINEERING DESIGN, METAL SELECTION

Physical and Mechanical Properties (including Fatigue and Creep). Corrosion and Wear. Engineering Design of Metal-incorporating Products. Selection of Metals and of Metal-Forms. Competition of Metals with Non-Metals. Specific Applications of Metals and Alloys.

Bearings and Bearing Surfaces

A Composite

Of all the contributions of metallurgical engineering to national security, hindsight will probably show developments in bearings, bearing design and bearing-surface technology to have been among the most significant. The speed and stamina of modern aircraft engines and other mobile military equipment is a direct result of the current availability of high fatigue-resistant, high corrosion-resistant, superlative surface-quality bearings and bearing metals.

Oil Temperature

Improvement in bearing life and performance has been effected not only by working on the metals as such but by attention to a host of corollary factors that have a determinable influence on bearing service. Thus, R. A. WATSON of Federal Mogul Corp. ("Oil Cooling—Its Relation to Bearing Life," *S.A.E. Journal,* Vol. 48, Feb. 1941, Trans. pp. 41-50) traces the somewhat surprising effect of oil temperature and its control on the metallurgical engineering properties and therefore the performance of engine bearings.

Of the various factors affecting the life of a bearing in an engine, fatigue strength is the most important. As the fatigue resistance of a bearing metal is related to its tensile strength, and the tensile strength is affected by temperature, bearing life is dependent upon the temperature of bearing metal. Investigation of bearing temperatures obtained in the field revealed that maximum temperatures were reached of sufficient magnitude to cause serious reduction in tensile strength.

Laboratory investigation showed that lubricating-oil temperature has the greatest effect on bearing temperature and that through control of the former, the latter could be reduced. Virtually all authorities on automotive-engine bearing design and lubrication recognize that the ideal crankcase lubricating oil temperature is about 180° F. With lubricating oil held at this temperature in a Diesel engine, the tensile strength of the bearing metal is 20-40% greater than that obtained under some trucking operation conditions, and the bearing life is correspondingly greater.

It is possible to maintain the lubricating-oil temperature at or below 180° F. in a large automotive Diesel engine, the best method of cooling the oil being the use of radiators in the air-blast. Heat exchangers utilizing engine cooling-water are not practical for engines where oil temperature control to 180° F. maximum is desired. Similarly, neither are jacketing the oil pan or using cooling-water coils in the oil pan feasible.

Metal Surfaces

Corrosion of bearing surfaces is an important engineering problem. E. A. SMITH ("Some Characteristics of Metal Surfaces," *Machinery, London,* Vol. 57, Feb. 13, 1941, pp. 541-544) points out that on every metal surface exposed to the atmosphere for some time, there are probably several compounds in addition to a mono-molecular layer of fatty acids condensed from the atmosphere. This surface cannot be observed by direct optical methods, but can be investigated with electron diffraction equipment.

The metal surface does not contribute to mechanical strength, but does offer resistance to corrosion, and affects the resilience, elasticity, and fatigue strength. The orientation of loosely or partially embedded crystals on the surface may decisively influence the all-important fatigue resistance. The effect of thin layers of foreign metals (*i.e.* zinc on steel) or of oxides (*i.e.* Al_2O_3 on aluminum) may greatly change these properties of the base metal.

The Beilby layer is associated with most bearing metals in operation. This layer has the unusual ability of dissolving at room temperature crystalline materials that may lie on it; ordinary surfaces do not have this property. The Beilby layer is also of interest in the conditioning of metallic surfaces; for example, colloidal graphite can be rolled into the Beilby layer on mild steel to increase its bearing properties.

The presence of an oxidized layer decreases the free surface energy of a metal and slows up further oxidation. The adsorption of polar molecules on bearing faces to form a saturated film is significant in problems of lubrication. The question of frettage corrosion has not been completely clarified; however, it is an atomic phenomenon occurring on the surface of metals under abrasion in the presence of oxygen.

Aluminum- and Lead-Base Bearings

More than one nation's engineers are presently concerned with the potential serviceability of aluminum-base or lead-base bearing alloys. In Germany, for example, M. F. VON SCHWARZ ("Zwei neuzeitliche Lagermetalle," *Tech. Zentralbl. prakt. Metallbearbeitung,* Vol. 50, May 1940, pp. 251-254; June 1940, pp. 304-306) has studied the engineering properties of such bearings. The alloys studied were (a) aluminum-base alloys low in copper, which carry the same surface loads as good lead-bronzes at ⅓ of the latter's weight, and (b) lead-base alloys that contain antimony and arsenic but no tin, and which are "equally as good" as tin babbitts.

The maximum bearing load is considered to be a good characteristic value of the quality of a bearing metal. Aluminum-bearing alloys are used as-cast and forged. They call either for provision of greater play in comparison with standard bearing alloys (due to their greater thermal expansion) or for thinner bearing linings. Long bearing lengths and lubrication grooves in the load-carrying part should be avoided. A perfect finish of the bearing surface, the use of pure mineral oil of appropriate viscosity, and constant filtering in a (Bosch) felt filter is recommended.

Regarding the lead-base alloys, their Brinell hardness and solidus temperatures correspond to standard German babbitt WM80. At low speeds, friction is even lower with the new tin-free alloy. The load carrying capacity and running properties of both types are about the same. The "emergency" bearing qualities of the new alloy are favorable. Surfaces should be finished smooth.

Certain German-bearing alloys of this type are specifically described by VON SCHWARZ in another publication ("Neue Blei- und Aluminiumlagermetalle,") *Abnahme,* No. 7, 1940, pp. 49-53; No. 8, pp. 57-59). "Palid" bearing alloys (11% Sb max., 7 As, bal. Pb) and "Quarzal" (15% Cu max., 10 Si max., + Mn, Fe, Ni, Cr, Mo, bal. Al) show favorable bearing properties, in some respects surpassing even the standard German babbitt WM80. The frictional values are between 0.0015 and 0.003. The bearing temperatures are so low that no cooling is required as is the case with lead-bronze at the same loads.

Zinc-Base Bearing Alloys

German attempts to develop zinc alloys for bearings have been watched here with considerable interest. RICHARD WEBER ("Gleiteigenschaften von Lagerlegierungen", *Z. Metallkunde,* Vol. 32, Nov. 1940, pp. 384-389) presents a comparison between zinc-base bearing alloys and standard materials. A constant-load machine of the Kammerer-Welter type was employed and details of the testing machine and conditions are given.

The following materials were studied: (1) zinc + 4% Al + 0.7 Cu + 0.03 Mg in the (a) cast and (b) extruded state; (2) zinc + 10% Al + 0.7 Cu + 0.03 Mg, (a) cast and (b) extruded; (3) tin + 11% Sb + 9 Cu; (4) lead + 15.5% Sb + 1 Cu + 10 Sn; (5) "Bahnmetall," containing lead + 0.69% Ca + 0.62 Na + 0.04 Li + 0.02 Al; (6) copper + 8-9% Sn + phosphorus; and (7) copper + 5% Sn + 7 Zn + 3 Pb.

At low speeds of 0.1 m./sec., considerable differences between the materials tested were found. Bearing alloys of the tin- and

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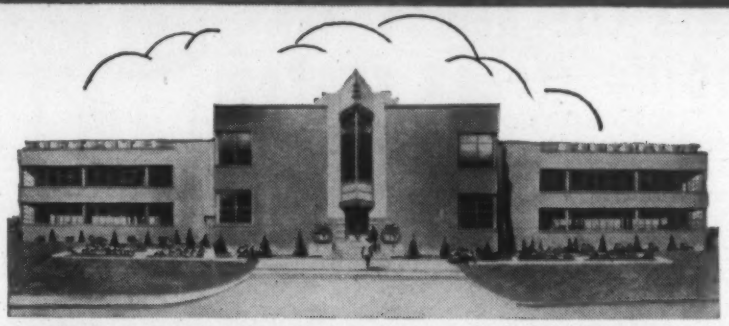

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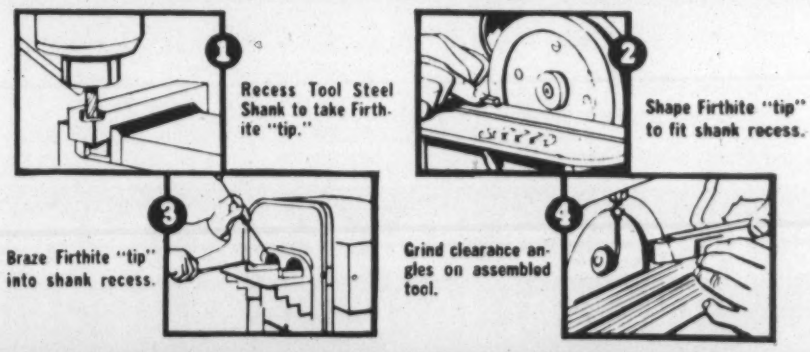

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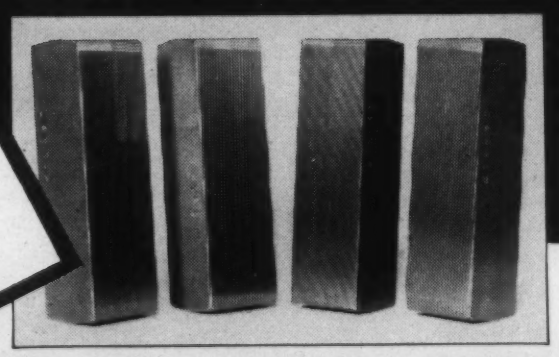

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lead-base types show the best gliding or "breaking-in" properties followed by phosphorus-bronze and alloy (7). At the rather high testing speed of 6 m./sec. the behavior at elevated temperatures and under more severe conditions is brought out. As to low-friction and high load-carrying ability at 0.1 m./sec., the new zinc-base alloy (2) is superior to the familiar die-casting alloy (1). With both alloys, the wrought material performs better than the cast alloys.

The lowest frictional values were observed with alloys (3), (4) and (5), while the phosphor-bronze and the zinc-base alloys were about the same. Alloy (7) showed the highest frictional values. At low speeds, the load-carrying capacity does not depend on compressive strength, but on the friction of the bearing surfaces.

As frictional values change in the same manner as bearing temperatures, the latter were only determined at 6 m./sec. in relation to rising loads. At higher loads, zinc- and copper-base alloys performed equally well. At low loads, alloys (3), (4) and (5) are about the same, but the order of merit at high loads is (5), (3), (4). Alloy (7) yielded the poorest results although it performed somewhat better at 6 m./sec. than at 0.1 m./sec.

In summary, at elevated temperatures, the zinc-base alloys are inferior to phosphor-bronzes, about equal to tin babbitt and lead-base alloys, and superior to (7). The wear of contacting surfaces of bearing and axle in case of irregularities or lubrication interruptions of the zinc-base alloys is comparable to (3), (4) and (5) and superior to copper-base alloys. The actual wear of group (1) and (2) is about the same as for tin-base babbitts and "Bahnmetall," but considerably higher than that of phosphor-bronze. X (3)

3a. Ferrous

High-Manganese Aircraft Steels

PROPERTIES OF QUENCHED AND TEMPERED STEELS CONTAINING MANGANESE AND OTHER ALLOY ADDITIONS ("Eigenschaften von Mangan-Vergütungstahlen mit weiteren Legierungszusätzen") H. CORNELIUS. *Stahl u. Eisen*, Vol. 60, Nov. 28, 1940, pp. 1075-1083. Practical.

The possibilities of substituting manganese for the molybdenum and nickel in the usual airplane structural steels containing 0.4% C, 0.9 Cr., 0.15 Mo; or 0.35% C, 2.12 Cr, 2.1 Ni and 0.3 Mo, were studied.

The compositions tried were (a) 0.35% C, 0.3% Si; 1-1.7 Mn, 0 or 0.3 Cr, 0-0.2 Mo, 0-0.3 V. (b) 0.27-0.41% C, 0.3-0.5% Si, 1.4-2.1 Mn, 0.6-1.9 Cr, 0 or 0.6 Ni, 0 or 0.2 Mo, 0-0.35 V. They were melted in a 16-lb. induction furnace and test samples forged to ¾ in. diam. The structure, sensitivity to overheating, hardenability in air, tensile properties after heat treatment, and temper brittleness, were determined.

In steels with over 1% Mn a small V addition reduced the sensitivity to overheating. The low-alloy steels containing manganese, when heat-treated to the usual tensile properties, had higher yield strength than comparable chromium-molybdenum steels. In the more highly alloyed steels the addition of vanadium to the manganese steels gave higher yield strengths.

Steels without molybdenum gave lower impact values. Temper brittleness was also diminished by vanadium. It was concluded that manganese steels could successfully be substituted for the chromium-molybdenum steels. Whether they could be substituted for the chromium-nickel-molybdenum steels was not certain. SE (3a)

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Welded Steel in Engineering Design

"How and Where to Use Welded Fabrication." R. B. White (Lewis Welding & Eng. Corp.) *Machine Design*, Apr. 1941, pp. 45-48. Descriptive review.

Thorough understanding of the welding process itself—its capabilities and limitations—is essential to a correct decision by the engineer on the use of welded fabrication instead of some other metal-form. Functional considerations should also not be forgotten in making such selections.

Weight reduction is an important factor recommending welded fabrication for many jobs, particularly mobile equipment. However, some machinery requires weight for stability and in such cases castings may prove more satisfactory. The ideal condition from the welding viewpoint is to effect a reduction in weight without loss of rigidity, as can often be done.

Properly designed steel weldments will be at least as rigid as iron castings because the modulus of elasticity of steel is practically double that of iron. However, designers should avoid a tendency to produce long unsupported surfaces in welded structures, for this, combined with reduced wall sections, may give structures that spring excessively under load. Proper reinforcing and support will avoid this difficulty. Rigidity or stiffness often becomes a deciding factor in favor of cast iron where pieces are small and a steel section of equivalent strength would be too flimsy, or a steel section of equal stiffness too expensive.

Another important property is resistance to vibration. Cast iron will dampen and absorb such vibration to a greater extent than steel, and greater care must be taken in designing welded units subject to this type of load. Proper arrangement of diaphragms will usually obviate this trouble.

With respect to direct costs, fabrication from steel plate, where only a few pieces are required, is likely to be cheaper than casting because the pattern cost is eliminated. In some cases machining can be done on small pieces before welding and thus eliminate the handling of a larger heavier piece. Frequently pieces that are made separately as castings can be combined into a single welding, thus saving the machining and bolting necessary to tie them together. It should always be remembered, however, that gray iron castings usually machine easier than steel weldings.

The more difficult machining of welded steel structures can often be circumvented by providing closer tolerances in welding with the help of proper jigs and fixtures, thus reducing the amount of machining required. Also, in weldments designs should be kept as straightforward as possible and offsets, bosses, holes, notches, etc. avoided, for costs will be increased considerably if much cutting, cleaning and grinding must be done on the plate.

Bent corners in weldments are superior to rounded outside corner welds; the former are just as strong and can be made more quickly and better-looking than the latter. Similarly, fillet joints should generally be used in preference to butt joints wherever this is consistent with good strength and appearance.

Close surface contact between two plates welded together cannot be expected unless special attention is paid to this requirement. Large pads will buckle and raise at the center through the shrinking action of the weld around the edges, unless plug welds are used. These must be made before the periphery is welded and will be better and cheaper if large holes are made 2-4 in. in diam. with a single fillet joining the edge of the hole to the plate below.

FPP (3a)

Q.E.D.

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3b. Non-Ferrous

Zinc in Germany

A Composite

Zinc is one of the few metals of which Germany has sufficient domestic sources to supply all her needs. For this reason the German literature has been filled for a number of years with papers on the properties and uses of zinc and its alloys—some the natural result of the metal's broad use and others part of a continuing propaganda program to effect substitution of zinc alloys for other (non-German) materials wherever possible.

Some excellent reviews of the technical situation with respect to zinc in Germany and reports of recent research on the metal and its alloys in that country appeared in year-end issues of *Zeitschrift für Metallkunde*, tardily reaching this country. Thus, G. Petrich & Wolf Wolf ("Zur interkristallinen Korrosion der Zinklegierungen," *Z. Metallkunde*, Vol. 32, Dec. 1940, pp. 412-414) studied the intercrystalline corrosion by moist steam of zinc alloys containing up to 10% Al and up to 0.3% Pb.

Among zinc-aluminum alloys with 0.1%

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Pb the least intercrystalline corrosion was observed in the eutectic alloy. Alloys with higher lead were very rapidly destroyed and even one with only 0.009% Pb revealed intercrystalline corrosion after 3 days' exposure. The phase rich in aluminum is particularly strongly attacked, the mechanism evidently being one of "galvanic" action at the expense of the aluminum.

The Germans appear to be concerned with avoiding *this* time their 1914-1918 difficulties traceable to the low recrystallization temperatures of zinc. According to G. MASING & H. J. WALLBAUM ("Ueber die Rekristallisationstemperaturen technisher Zinklegierungen," *Ibid.*, p. 418) the recrystallization of modern zinc alloys presents no serious problem, even with higher cold-working reductions; so long as the recrystallization results in a fine grain, there is no detrimental effect on physical properties.

"Creep" Properties

A realistic attack on the creep property question, based on recognition that in the case of zinc alloys the structure is of more importance than nominal composition, is reported by A. BURKHARDT & E. GWINNER ("Die Dauerstandsfestigkeit von Zinklegierungen," *Ibid.*, Nov. 1940, pp. 390-398). The behavior of zinc alloys under constant static loads in relation to grain size, extrusion speed, extrusion temperature, deformation texture, amount of plastic deformation and heat treatment is studied.

The extruded rods carried a load of 2700 lbs./in.^{2} and the stretching of the samples was observed for 200 hrs. [*The testing temperature is not given, so it is probably room temperature.*] In case of insufficient (unmeasurable) "creep," the load was doubled. The tests were supplemented by bending and X-ray tests.

Fine-grained zinc of 99.99% purity extruded at *low* speeds show greater creep than when extruded at *high* speeds, especially in zinc alloys containing 2% or 4% Cu. In all cases, creep rates were greater during the first couple of hours than afterwards. The bending tests corroborate the creep test results, *i.e.* a coarse-grain, less bendable material is more creep resistant.

The commercial magnesium-bearing zinc alloys with 4% Al and 1 Cu and with 15% Al yielded better results, but their creep resistance also depends on extrusion speed. Keeping the latter constant and varying the extrusion temperature between 480° F. and 680° F. proved that low extrusion temperatures result in fine grain and low creep resistance. A brittle 1% aluminum-zinc alloy wire breaks on slow bending, but withstands 20 bendings at a speed of 2 bends per sec.

Regarding the deformation texture, drawn magnesium-free alloys containing 4% Cu, or 1% Al, or 4% Al + 1% Cu show better creep resistance than extruded alloys, but conditions are reversed with the higher aluminum-bearing alloys with 15% Al or with 10% Al + 2% Cu. The zinc alloy containing 4% Cu shows marked improvement of creep resistance after reductions as low as 3%. Above 15% reduction no further improvement is achieved.

The aluminum-bearing alloys show the opposite behavior, *i.e.* deterioration of creep resistance with plastic deformation. However, it appears that small additions of magnesium exert a strong counteracting effect on creep resistance. In agreement with former literature statements, it was found that the annealing of cold drawn zinc alloys improves their load-carrying ability.

As to alloy additions, nickel improves the creep resistance of 99.99% Zn only in amounts higher than 0.5%, while 0.03% Mg is twice as effective. With a base alloy of 4% Cu, 0.2% Al, bal. zinc, drastic improvement in creep resistance was achieved by adding 0.04% Mg. Lithium has a similar though less pronounced effect. Manganese additions exceeding 0.5% and also nickel cause marked improvement, while iron has but a mild effect, unless in the presence of manganese. Cadmium, sodium or potassium offer no advantage.

The authors recommend for maximum creep resistance the use of a maximum extrusion temperature of 600° and 715° F., respectively for aluminum- and copper-bearing zinc alloys; the use of extrusion speeds of about 1-2 m./min.; the development of a grain size of 300μ^2; the use of copper-bearing zinc alloys in the cold-worked state (15% reduction) followed by annealing at 700° F.; the use of aluminum-bearing zinc alloys in the extruded state together with additions of magnesium (0.04%), lithium (0.05-0.15%), and manganese (0.5-0.8%).

Somewhat similar results were obtained by K. LÖHBERG & F. WOLLBANK ("Härte-Kriechversuche an Zinklegierungen," *Ibid.*, Dec. 1940, pp. 419-424), who used as a measure of "creep resistance" the penetration speed of a 2.5 min. steel ball at 31.25 kg. load during a testing time of 20 min. Most of the tests were made at room temperatures; some parallel tests at 200° F. showed the results to be along the same lines. Better results were obtained with ternary zinc-aluminum-copper alloys than

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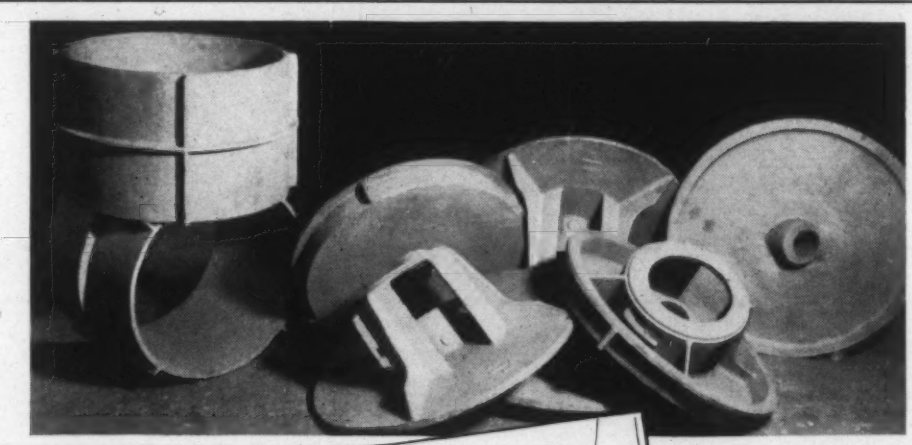

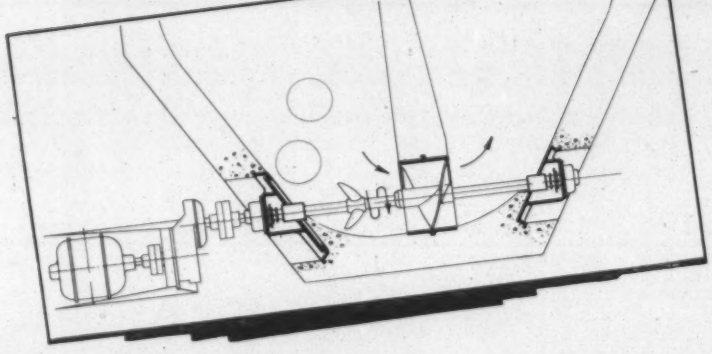

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with binary zinc alloys. The beneficial effect of magnesium additions was noted, as was the deleterious influence of increasing cold work on the binary zinc-aluminum alloys. According to these authors, coarse recrystallization does not affect the creep characteristics.

Electrical Conductors

A wealth of data on the properties of zinc and its alloys of interest to the electrical industry is given by C. HAASE & F. PAWLEK ("Zink und Zinklegierungen für Leitungszwecke," *Ibid.*, Oct. 1940, pp. 327-335) and considerable information on German practical experience with such applications is found in the discussion (*Ibid.*, pp. 335-339). Difficulties due to embrittlement of zinc are still encountered with high purity zinc at about 200° F., but in contradistinction to World War I alloys, modern high purity zinc and its alloys are safe for service in steam atmospheres, and are not nearly so subject to intercrystalline corrosion.

The conductivity of zinc, which is ¼ that of copper and ½ that of aluminum, does not drop sharply with small additions of other metals, as copper does. The strength of 99.99% pure zinc is small, yet greater than that of soft or half-hard aluminum used for insulated cables. Contaminations of the order of 0.1% in "pure" zinc make it harder than annealed copper.

A careful and critical comparison of 99.9%-pure zinc, 99 Zn/1 Al and 96 Zn/4 Al and aluminum indicates that the 99 Zn/1 Al alloy is suitable as conductor material for lead wires, bus bars, etc., but for other, heavier duty purposes zinc and its alloys are unsuitable because of their low conductivity and low creep strength.

EF (3b)

Copper-Nickel Alloys in Seawater

"THE BEHAVIOR OF NICKEL-COPPER ALLOYS IN SEA WATER." F. L. LAQUE (Int. Nickel Co.) *J. Am. Soc. Naval Engrs.*, Vol. 53, No. 1, Feb. 1941, pp. 29-64. Review.

Many corrosion tests are cited under both laboratory and outdoor exposure conditions in which a series of copper-nickel alloys were compared with pure copper and nickel under the same conditions. It is usual for the corrosion resistance to increase with the per cent of added nickel. In most cases the 70% Ni, 30 Cu alloy (Monel) is most resistant, but occasionally pure nickel appears slightly higher in corrosion resistance. The high resistance of nickel-copper alloys to impingement attack, such as occurs in condenser tubes with high rates of flow, is noted for the applications made of the 70-30 alloy in many large passenger ships.

The problem of protecting ships bottoms against fouling by marine growths is indicated as one that follows the copper content rather closely. Where the copper content is 60% or more the concentration of copper salts is sufficient to prevent the growth of barnacles, etc., and when the copper drops to below 50% fouling is likely to occur. For copper contents between 50 and 60% the alloy is anti-fouling if the conditions of service are such as to corrode the alloy at a fast enough rate to supply the amount of copper salts required for protection; on the other hand, the anti-fouling characteristics of the alloys containing around 30% Ni are not associated with distinctive rates of corrosion.

The pitting type of corrosion attack is particularly troublesome whenever it occurs. Susceptibility to this type of attack increases with the nickel content of copper-nickel alloys, with the exception of the

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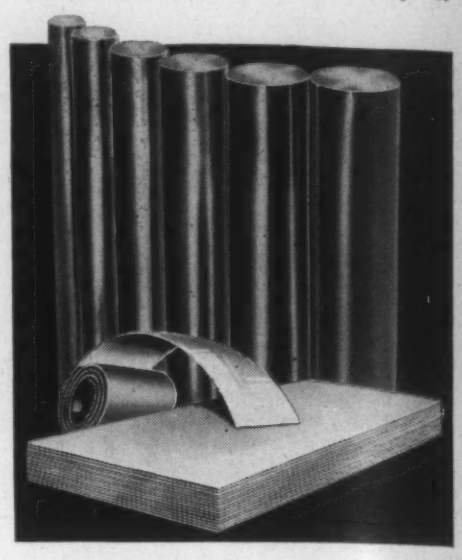

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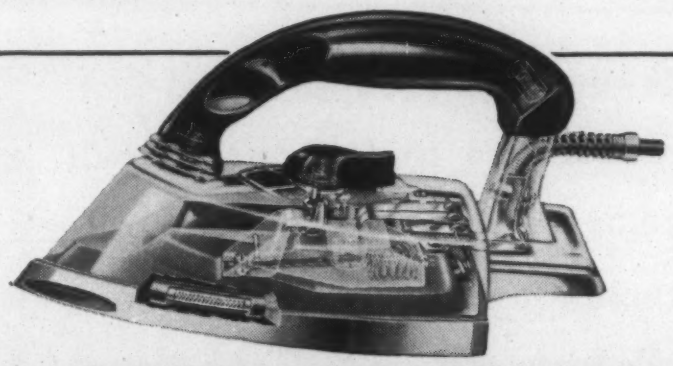

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70% Cu, 30 Ni alloy. The latter does not have complete resistance to pitting, but when pits start they tend to widen out rather than deepen. Of the entire series, nickel has the greatest tendency toward pitting and copper the least.

The possibility for oxygen or concentration cells to form under the area covered by an attached marine organism is likely, particularly when the organism is dead and supplies sulphur compounds formed during decomposition. For the higher nickel alloys, which are not anti-fouling, this local attack under the marine organism may be expected.

Waterline attack on copper is severe and on copper-nickel alloys with nickel in excess of 30% it is practically negligible. Service data on the 70% Cu, 30 Ni alloy as sheathing for ships indicates its entire suitability for such use. Selective attack such as occurs in the dezincification of copper-zinc alloys does not occur with copper-nickel alloys and the addition of 4% Ni to copper-zinc with 60/40 ratio makes the latter not susceptible to dezincification.

The galvanic relationships of a series of metals and alloys are discussed with a tabulation from another publication and a curve from which serviceable combinations can be selected for use in seawater. The intensity of the galvanic effect is determined by the potential developed by the galvanic couple, by the polarization characteristics of the metals and by several other factors, such as relative areas exposed. It appears to be unwise generally to combine materials where the area of the material higher in the galvanic series is relatively small compared to that of the material lower in the series. WB (3b)

Aluminum-base Dental Alloys

MECHANICAL PROPERTIES AND CORROSION STABILITY OF DENTAL ALLOY BASED ON HIGH-PURITY ALUMINUM ("Festigkeitseigenschaften und chemische Beständigkeit einer auf Reinstaluminiumbases entwickelten Aluminiumlegierung für die Zahnheilkunde") KURT ROSENTHAL & WERNER GELLER. *Z. Metallkunde,* Vol. 32, Oct. 1940, pp. 348-355. Original research.

Aluminum-base dental alloys are not new, but their development received a new impetus with the production of aluminum of highest purity and of increased corrosion resistance.

The authors have developed a precipitation-hardening dental alloy made of ultra-high purity aluminum to which is added 0.8% Si, 0.7 Mg and 0.2 Ti. The presence of titanium refines the grain markedly and raises the hardness but slightly; corrosion resistance is appreciably improved, as measured in the standard (German) dental alloy corrodant of 1% lactic acid + 0.25% sodium chloride.

The alloy is salt-bath-annealed at 985°-1060° F. for 5 min. (or 15 min. in air) and water-quenched. Aging at room temperature or hardening for 2 hrs. at 355° F. is recommended. Solution-annealing and quenching induces a high corrosion stability, which is impaired but slightly by precipitation-hardening.

Increasing the iron content to more than 0.02% entails a considerable loss of corrosion resistance, and in particular leads to the occurrence of intercrystalline corrosion in castings. The wrought alloys are more stable than cast. Great variations in the corrosion weight losses were observed depending on the kind of lactic acid used. Brinell hardness of almost 100 and tensile strengths of about 42,000 lbs./in.^{2} were obtained on the hardened alloys. EF (3b)

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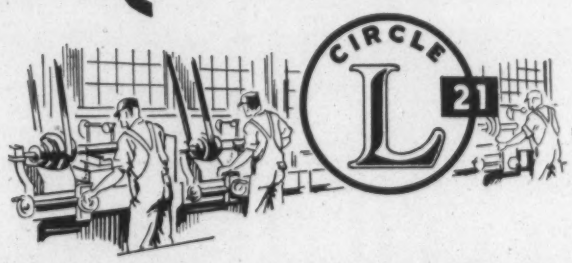

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Electro-Etching Magnesium Alloys

AN ELECTROLYTIC ETCHING METHOD FOR WROUGHT MAGNESIUM ALLOYS ("Ein elektrolytisches Ätzverfahren fur Magnesium - Knetlegierungen") RICHARD MECHEL. *Z. Metallkunde,* Vol. 33, Jan. 1941, pp. 34-36. Descriptive.

Standard etching methods given in the literature are often impractical on the more recently developed and complex magnesium alloys containing aluminum, zinc, cadmium and bismuth. Difficulties in polishing may be overcome by suspending magnesia in a 10% aqueous solution of concentrated sodium hydroxide. For the electrolytic etch, copper cathodes operating at 4 volts, 0.53 amps./dm.^{2} in an electrolyte of 10% NaOH.

The etching must immediately follow the polishing operation; otherwise the sample is washed in 10% NaOH, then in 5% NaOH, followed by distilled water and alcohol. The etching time varies depending on the alloy (2-4 min.).

A more uniform etch is obtained by adding 0.06 mg. copper per 1 cc. electrolyte. In all cases the cathode must be larger than the sample to be etched. Although the standard 0.5% alcoholic nitric acid solution yields good results on the standard magnesium alloys containing aluminum or manganese, the electrolytic etch presents a new effect as it attacks the grain in a manner similar to macroscopic etching. It is particularly adapted to the study of welds in magnesium alloys. EF (4)

X-Ray Diffraction and Fatigue

"X-RAY STUDY OF THE CHANGES THAT OCCUR IN ALUMINUM DURING THE PROCESS OF FATIGUING." R. G. SPENCER & J. W. MARSHALL (Albion College) *J. Applied Physics,* Vol. 12, Mar. 1941, pp. 191-196. Experimental.

Fatigue specimens prepared from 17S-T aluminum alloy were studied with Fe-K radiation at or near one particular spot in each specimen after subjecting the specimen to increasing amounts of cyclic stress of chosen value. Some 30 test bars were studied and the chosen stress values ranged from 11,000 lbs./in.^{2} to 32,000 lbs./in.^{2} (The rated endurance limit of the alloy used is about 13,000 lbs./in^2 at 10^8 cycles.)

From their results the authors conclude: Fatigue failure of 17S-T is preceded by fatigue damage that may be detected in the X-ray diffraction pattern, contrary to the results of Kies and Quick (*Nat'l. Adv. Comm.* Aeronautics, Reprint No. 659, 1939), most of the detectable change oc-

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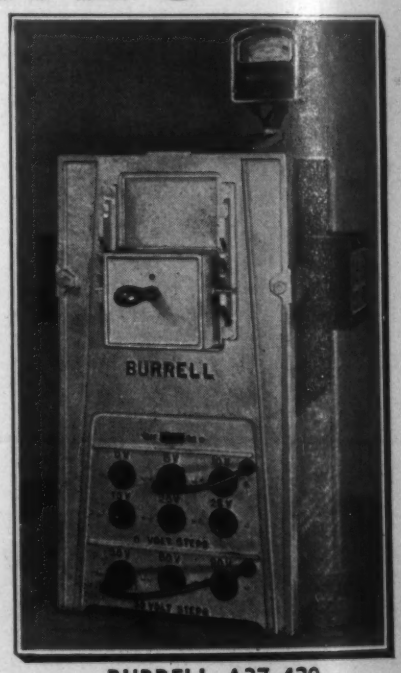

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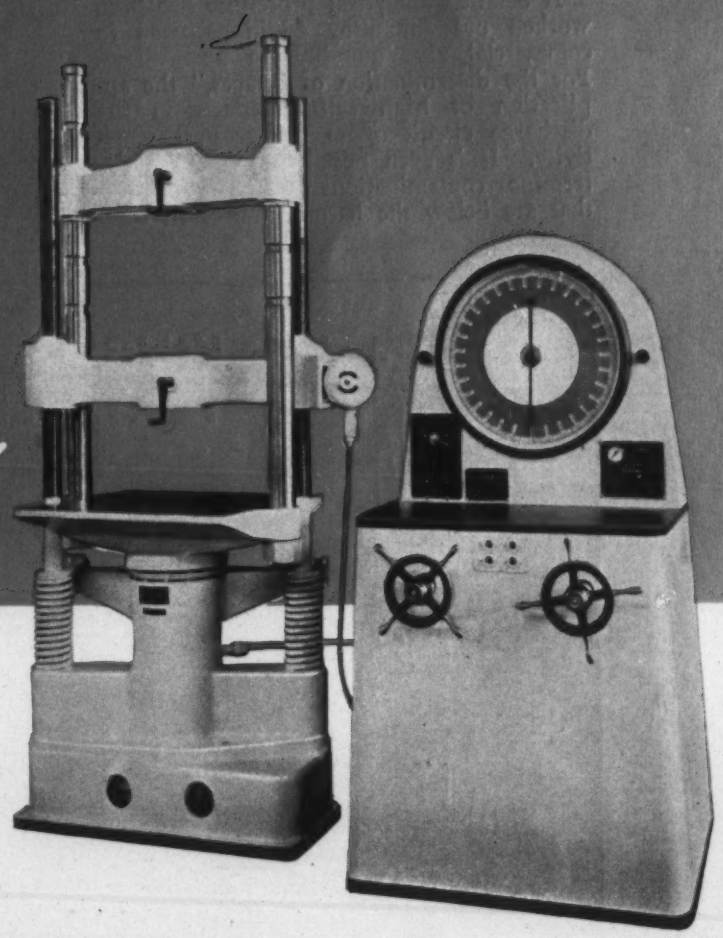

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curs in a small fatigue range immediately preceding failure.

Changes are not observed when the applied stress is below the fatigue limit—a view that is not supported by Barrett (see METALS AND ALLOYS, Vol. 8, Jan. 1937, pp. 13-21). Repeated cyclic stress starts intercrystalline weakness, leading to failure. HFK (4)

Spectrography of Zinc, Aluminum

A Composite

Spectrographic complications introduced in zinc alloys by their aluminum content, and in aluminum alloys by the zinc present, have been separately attacked by 2 German workers and the results can be appropriately summarized together.

The interfering effect of aluminum in the spectroscopic analysis of zinc alloys was studied, and ameliorating conditions suggested by F. WOLLBANK & G. LUEG ("Verfeinerung der Spektralanalyse von Feinzinklegierungen," *Z. Metallkunde*, Vol. 32, Dec. 1940, pp. 430-436). The analytical results become more reliable the greater the size of the condenser used and the lower the self-induction; this holds for aluminum-contents of 2-13%. Difficulties were still encountered in zinc alloys containing 0.5-2% Al. No complication is introduced by copper (tested up to 6%) and magnesium (0.1%).

A detailed analytical procedure has been worked out for alloy additions used in commercial aluminum-bearing zinc alloys. For the determination of "traces," the application of high self-inductions in the discharge circuit offers the greatest sensitivity. It is even possible reliably to determine contaminations at concentrations that are below the harmful range in commercial alloys. Such a determination of "traces" may be combined in one operation with a complete quantitative analysis if the aluminum content is higher than 6% and if it does not vary greatly. Remarkable simplification of the control analysis procedure for the standard zinc alloy "Zamak-beta" (10% Al, 1 Cu) has been developed.

The foregoing authors demonstrated among other things that about 1% Zn in aluminum alloys affects the aluminum spectrum. A new method for the spectrographic analysis of aluminum alloys in which the interfering effect of zinc is eliminated is reported by A. BEERWALD & W. BRAUER ("Ueber die Spektralanalyse der Aluminiumlegierungen," *Ibid.*, Vol. 33, Jan. 1941, pp. 44-45).

The method comprises dissolving one gram of the alloy in 100 cc. of an HCl solution, and impregnating a carbon electrode with this solution by means of a platinum wire loop. The accuracy for 3 different pairs of lines from an aluminum alloy with 9% Mg was determined and showed the best results for Mg 2780/Al 2660 m = ± 3%. EF (4)

Magnaflux Testing

"MAGNAFLUX INDICATIONS RATED BY PROPOSED METHOD." *S.A.E. Journal*, Vol. 48, Jan. 1941, pp. 18-19. Descriptive.

Proposed S.A.E. recommended practice for expressing and recording magnaflux patterns have been submitted by the Iron and Steel Division of the S.A.E. Standards Committee. The system is a simple code whereby the number, length and distribution of magnaflux lines may be expressed on the basis of a sq. ft. of surface examined, regardless of the size of sample. For convenience in handling and counting, the sample should be not less than 5 in. long.

The system is not intended as a direct index of quality, but rather as a shorthand description of the indications observed. Code factors are (1) the total number of lines per ft.^{2}; (2) aggregate length of all lines per ft.^{2} to nearest in.; (3) length of longest single line to nearest 0.1 in.; and (4) letters indicating uniformity of distribution. *A* indicates uniform distribution; *B*, a slight tendency toward grouping; *C*, an arrangement of discernible groups; and *D*, well defined or concentrated groups or clusters.

To distinguish indications of exceptionally heavy nature, *H* may be added to the figure for item (3). If average lines rather than only the longest line is heavy, *H* may be added to the figure for item (2). Indications of "pepper-and-salt" nature less than 0.1 in. long are not to be counted as lines but are regarded as background and, unless in large numbers, will be disregarded. When in large numbers, their presence will be mentioned after the items by appropriate descriptive words.

Where indications of less than 0.1 in. long occur in "ranks" or strung out end to end, they will be counted as lines whenever spaces between them are less than 0.1 in. across. When interruptions are more than 0.1 in. across, these short indications will be disregarded.

As an example, a 6 x 6 in. sample has 42 lines. As the area of the sample is ¼ ft.^{2}, the total number of lines per ft.^{2} is 168. The total length of all the lines on the surface of the sample is 5 in., making the aggregate length per ft.^{2} 20 in.

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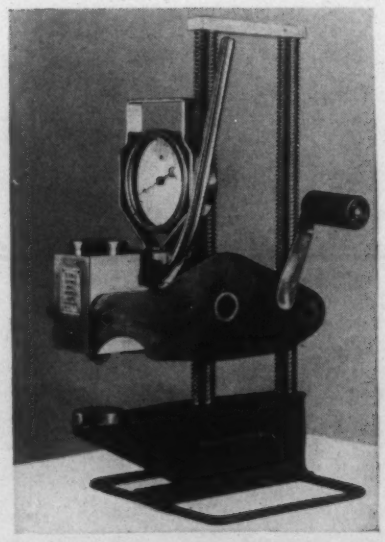

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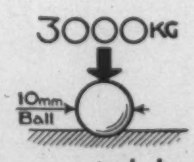

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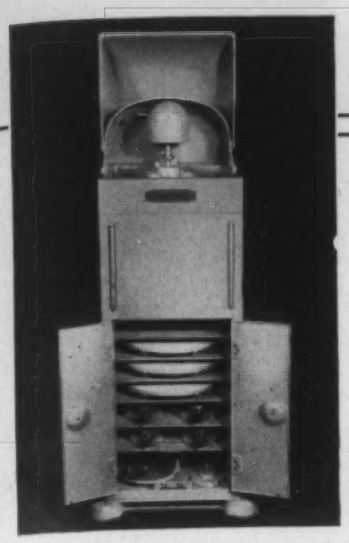

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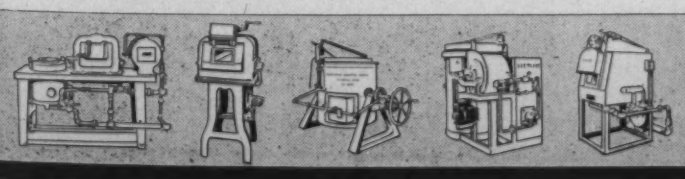

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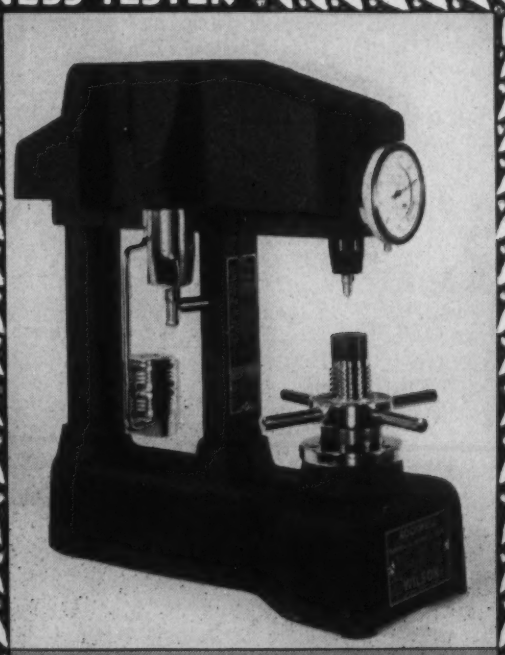

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The longest line is approximately ¾ in., making this item 0.7. If this line were heavy, this item would read 0.7 *H*. The lines are arranged in distinct groups, so that *C* is used to describe the distribution of the lines. Thus, the code number would be 168-20-0.7 *H-C*.

The general recommendations include that the standard of acceptance or rejection of material should be a matter of agreement between producer and user; the method of testing should be representative of the wet continuous method; not less than 700 and not more than 1200 amp. d.c. per in. sample diameter should be used, and, in no case, should the amount of current used be enough to indicate the flow lines if such are present; not more than 3 "shots" should be used.

In addition, it is recommended that the relay timing should be 1/5-½ sec. per "shot"; the entire testing operation should consume 3-5 sec.; when using the flowing-on method of applying the vehicle containing the magnetic substance, the application should not continue after cessation of current flow; a uniform suspension of magnetic substance in the vehicle should be maintained; concentration of the magnetic substance in the vehicle should be maintained between 1% and 1¾% maximum; and the specimen to be tested and examined should be as representative as is practicable of the finished part.

It is particularly important that the diameter be approximately that of the finished part, unless otherwise agreed between producer and user; the sample should be heat treated or otherwise prepared to simulate the properties and condition of the finished part and have a turned or otherwise prepared finish at least equivalent to 20 micro-in. (r.m.s.); and in all cases the sample should have a machining operation sufficient to remove all surface defects resulting from forging, rolling, heat treating, etc. MS (4)

Scratch Hardness Testing

SCRATCH HARDNESS IN C-G-S UNITS ("Die Ritzhärte in c-g-s Einheiten") WOLFGANG EHRENBERG. *Z. Metallkunde*, Vol. 33, Jan. 1941, pp. 22-23; also QUANTITATIVE RELATIONS BETWEEN SCRATCH HARDNESS AND PENETRATION HARDNESS ("Quantitative Beziehungen zwischen Ritzhärte und Druckhärte") *Ibid.*, pp. 23-24. Original research.

Scratch hardness is related to workability and wear resistance. The author attempts to correlate penetration hardness and scratch hardness by expressing the latter as the load per unit of gliding surface, just as penetration hardness is expressed as load per unit of indentation area. Hitherto it has been possible only to compare different kinds of scratch hardnesses one with another, but in this work scratch hardness for the first time has been quantitatively correlated with penetration hardness.

Experiments were made on different ferrous and non-ferrous materials, glass, etc. using (a) a ball of 8 mm. diam., (b) a cone with 120° tip, (c) a triangular pyramid with 150° top angles. The loads applied ranged between 1¼ and 10 kg.

For this load range, penetration and scratch hardnesses yielded practically the same results for (b) and (c) with reference to all metallic materials tested, *i.e.* steel, iron, aluminum and magnesium alloys. Using the 8 mm. ball, an agreement between both types of hardness was found only for soft materials like pure aluminum, and magnesium alloy. For hard materials like duralumin, steel and iron, the scratch hardness was about twice as high as the penetration hardness.

The usefulness of scratch hardness tests is shown by the fact that heat treatments of steel may double its Brinell hardness, while the wear resistance actually decreases, whereas scratch hardness tests rate the surfaces according to their actual wear resistance.

A number of aluminum- and magnesium-alloys—plain, clad or surface-treated—hard and soft lead-bearing alloys, electrolytic chromium-platings, 2 kinds of glass and lacquer coatings on light metals were tested by the indentation and scratch hardness methods in relation to loads varying between 5 and 1000 g. The standard Martens scratch hardness tester was used for the load range 5-50 g. A diamond cone with a 120° tip was employed.

At higher loads, the scratch hardnesses are slightly higher than the penetration hardness values, but approach each other with decreasing loads and then differ widely at very small loads. Scratch hardness is obviously greatly affected by the grain size. If the depth of penetration becomes smaller than the grain diameter, the scratch hardness tends toward higher values, while the penetration hardness tends toward lower ones.

The scratch hardness of surface-treated aluminum- and magnesium-alloys naturally depends on the treatment, some of which greatly reduce the strength of the surface layers. EF (4)

Close Temperature Control

MODERN REFINEMENTS FOR ACCURATE THERMO-ELECTRIC TEMPERATURE MEASUREMENT, RECORDING AND CONTROL FOR INDUSTRIAL PURPOSES AND RESEARCH ("Ueber neue Geräte zur genauen thermoelektrischen Temperaturmessung, Aufzeichnung und Regelung für Industriebetrieb und Forschung") ERNST WEISSE. *Z. Metallkunde*, Vol. 33, Jan. 1941, pp. 1-13. Descriptive.

The development of precipitation-hardening alloys in recent years has increased the requirements for accurate temperature control to within 3° or 5° F. in the shop. Also in the research laboratory, there is a demand for an instrument for temperature measurement and control that permits the recording of rapid temperature changes with the highest degree of accuracy.

The author feels that temperature measuring instruments available at present do not fully meet these requirements. He reviews the methods and equipment for thermo-electric measurements, including important American developments, and reports his own experience with an automatic compensator in a temperature recorder. Literature statements regarding the changes of e.m.f. on long heating times are in disagreement, excepting for the noble metals.

Recent iridium - ruthenium / iridium - rhodium thermo-couples have pushed the temperature range to 3800° F. The embrittlement of the nickel-leg of nickel/nickel-chromium couples can be avoided by an alloy addition of aluminum [*result: the Chromel-Alumel couple*]. Gas absorption of the iron-leg in iron/constantan couples causes changes of e.m.f. The trend has been toward noble metal couples with lower e.m.f.'s and thus, more expensive instruments. Some 22 diagrams showing the wiring of instruments for temperature measurement and control are discussed at length and somewhat critically.

As a step forward, the application of a photocell compensator is emphasized which "in comparison with American and English instruments, which incorporate a great number of mechanically-actuated parts and switch members, is surprisingly simple." [*American-made control instruments operating on an electronic, no-contact basis have been available for some time.*—F.P.P.] By using a dotted-curve recorder, a recording accuracy of 0.3% with an adjusting time of 3 sec. has been attained. The author describes his installation at the Technische Hochschule, Berlin and its application to a thermal analysis of ternary aluminum-nickel-silicon alloys, showing a response to minute thermal effects. EF (4)

Sheet Steel Thickness Gage

"A GAGE FOR MEASURING THE THICKNESS OF SHEET STEEL." B. M. SMITH & W. E. ABBOTT (Gen. Elec. Co.) *Gen. Elec. Review*, Vol. 44, Feb. 1941, pp. 125-127. Descriptive.

Measuring the thickness of sheet steel from one side only has been made possible by a new magnetic thickness gage. With it, thickness measurements of large magnetic sheets is a simple process—the operator need only place the gage head on the sheet or slide it over the surface, noting the reading indicated on an electrical instrument calibrated in thickness units.

The gage consists of an indicating unit and the gage head. Power is supplied through a lead to the indicating unit, which is connected to the gage head by means of another flexible lead. The indicating instrument is ordinarily furnished with a double scale; one scale (20-45 mils) is calibrated for low-carbon steels, either hot- or cold-rolled, and the other (10-25 mils) for magnetic sheets of medium silicon content. Special scales can be furnished for other metals having different saturation characteristics.

The gage is portable and easy to handle. The indicating instrument measures approximately 7 x 6 x 6 in. The total weight is only 7¾ lbs. of which the gage head represents ¾ lb. Sheets of any size can be measured for thickness, and the gage can be adapted to measuring the wall thickness of pipes.

The gage is calibrated to cover those grades of sheet steel most commonly used. It must be recalibrated for any grade in which the magnetic saturation differs greatly from that for which the instrument is calibrated. Thickness standards are furnished for checking the calibration of each scale. The standards are normally 14 and 25 mils thick for the silicon steel and 20 and 45 mils thick for the cold-rolled steel. The calibration may also be checked by comparison with a caliper-type gage.

The accuracy of the standard gage is within approximately 1 mil on the 10- to 25-mil scale and 2 mils on the 20- to 45-mil scale. In comparing one part of a sheet with another or in comparing sheets of the same grade the accuracy is within 0.5 mil. The precision of the gage is limited only insofar as the magnetic properties of the steel vary near saturation.

Since the measurement is an average of the thickness of the material under the edge of the center pole of the measuring head, where the flux density is maximum, it is apparent that the measuring head must make close contact with the sheet. However, a non-magnetic coating on the sheet introduces an error in the thickness reading less than the thickness of the coating itself. Accuracy is sacrificed if the gage head is closer than ½ in. to the edge of the sheet, or if the sheet is backed up by other magnetic material. (4)

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trends

By Edwin F. Cone, Editor

Expansion in Welding

National defense could never reach its goal without the welding industry, said K. L. Hansen, consulting engineer with the Harnischfeger Corp., in a recent address. "Some manufacturers of metal products now providing material for the Government employ thousands of welders. Every arsenal in the United States has full welding equipment. In fact, welding has grown in 23 yrs. to be one of the most important tools in modern production," he said.

Iron Ore for Germany

The iron and steel industry of Germany has been greatly strengthened in the last year, according to the Department of Commerce, which cites German press reports. The Continental ore situation has been changed as a result of the Norwegian campaign, the acquisition of Lorraine and the relations with Luxemburg. Ore reserves within Germany have been developed so that the goal of the Four-Year Plan of 25,700,000 metric tons has been reached.

Iron and Steel Imports

Only 406 tons of iron and steel were imported into the United States in January—a new low record, says the Bureau of Foreign and Domestic Commerce. Sweden, with a total of 226 tons, was the chief source, mostly flat wire and strip steel.

A. F. A. Chapters

One of the important trends in the progress of the American Foundrymen's Association has been the establishing of local chapters since the founding of the first one in Chicago in 1934. The 20th chapter in Western Michigan was recently announced.

Substitute for Aluminum Foil

From many quarters one reads of proposed substitutes for some essential materials. The Reynolds Metals Co., the largest manufacturer of aluminum foil, announces a new product described as "Reynolds Plastic Finish," produced by "coating a highly calendered paper board with an aluminum powder compound made from scrap, covered with a clear or colored plastic finish."

Tin

The Tin Research Institute reports that world production of tin for the first two months of this year was 35,200 tons against 30,800 tons for the same months in 1940. United States deliveries for the same period this year were 24,955 tons as compared with 16,380 tons last year to March 1.

More Aluminum

To meet the rapidly expanding demand for aluminum, the Reynolds Metal Co. will soon increase its total capacity to 100,000 tons annually. The first plant at Sheffield, Ala., with a capacity of 40,000 tons per year, is being supplemented by a 60,000-ton plant at Bonneville Dam. Government financing to a total of over $35,000,000 is involved.

Cuban Manganese Ore

We are receiving from Cuba the largest amounts of manganese ore in history. In the first 40 days of this year, imports were at the rate of about 145,000 tons per yr. The 1940 volume was 130,645 tons.

Manganese Ore

An encouraging trend was the upswing in the imports of metallurgical manganese ore last year. Receipts for consumption were 1,254,588 gross tons against 627,131 tons in 1939. General imports were 1,268,153 gross tons as compared with 698,490 tons in 1939. This ore is the basis of ferromanganese, essential in the manufacture of steel.

Tungsten

A possibly encouraging report concerning our supply of tungsten, much of which is imported, comes from the Bureau of Mines. A discovery which may be of great importance is that, in the antimonial gold ore districts of Idaho, deposits of scheelite (a tungsten ore) have been uncovered which may prove a source of domestic tungsten.

(Additional "Trends" on page 660)

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trends

By Edwin F. Cone, Editor

Substitutes for Priority Metals

According to reports in the daily and technical press, there is a wide scramble for substitute materials for metals now on the priority list—aluminum, magnesium, zinc, nickel, certain alloy steels, and so on. The Ford Motor Co., as fast as parts are changed, displays the new ones alongside those they replaced. Changes already mapped out in the making of automobile parts will mean a saving of 80 per cent nickel, 50 per cent in aluminum and 50 per cent in zinc. In many cases the new parts are said to be better than the old. Magnesium is no longer used and 8 to 10 aluminum tractor parts will be or are being replaced with iron and other ferrous materials. Steel stampings are replacing zinc die castings and malleable castings for other parts. Plastics will replace zinc instrument panels, etc. and radiator shells will be made of copper instead of brass.

Open-Hearth Progress

Discussing some of the changes that have taken place in open-hearth practice in the last 10 yrs., S. C. Davis in an article in the *Atlantic Monthly* for March, evidently on the authority of L. F. Reinartz, says that the average roof life of a furnace used to be 100 to 150 heats; it is now from 300 to 350 heats—reducing the cost of steel by $1 a ton. Where insulation has been applied generally below the charging floor level, a 5 per cent increase in melting area and a 7 per cent decrease in fuel consumption have resulted.

More Electric Steel

The new electric steel plant of the Copperweld Steel Co., Warren, Ohio, is adding 4 electric melting furnaces bringing its capacity to approximately 20,000 tons per month. The total number of furnaces in that plant will be 6 by May 1.

Steel Casting Output

Production of steel castings in 1940, according to the Department of Commerce, was 797,947 net tons as compared with 594,147 tons in 1939 and 342,737 tons in 1938. It is stated that the average operation of the industry last year was 56.8 per cent of capacity with that for December at 73.3 per cent. This upward trend bids fair to be intensified in 1941.

Aluminum from Clay

Aluminum from clay is a possibility, according to D. E. Lilienthal, director, T.V.A. The practicability of the process has already been proved, he claims, and he hopes that the production and cost ratio will be favorable. The new process might yield 1 ton of aluminum from 6 tons of clay containing 33 per cent Al—approximately the yield of bauxite ores of the same content, he alleges. Similar hopes, expressed by others, have not borne fruit. The technology can be licked more readily than the economics.

World Steel Output

The output of steel in the world in 1940 is estimated at about 159,000,000 net tons—a new record—says the American Iron and Steel Institute. This total exceeds by about 6 per cent the previous record of 150,300,000 tons in 1939, due largely to the sharp increase in this country last year. The American output last year of nearly 67,000,000 tons represents 42 per cent of the world production—greater than the combined output of Germany, U.S.S.R., and England.

Organizing for Defense

Containing 54 questions and answers, a pamphlet of the American Iron and Steel Institute explains in lay language the steel industry's part in the Defense Program. It tells how the chief executives of about 30 steel companies are organizing to promote the rearmament programs.

Manganese Ore Supplies

By Government purchases of 800,000 to 900,000 tons, the supply of metallurgical manganese ore will be sufficient for two or more years, said R. C. Allen in a recent address.

Steel Output 100 Per Cent

Recent steel ingot operations of the American steel industry have averaged 100 per cent of capacity with some districts higher—Pittsburgh, 101.50; Buffalo, 106; and St. Louis, 111 per cent.

(Other "Trends" on page 658)